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PLANTERS' RECORD

VOL. XXXVI

A quarterly paper devoted to the sugar interests of Hawaii, and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XXXVI

H. P. AGEE, *Editor*

H. L. LYON
J. A. VERRET
OTTO H. SWEZEY
W. R. McALLEP
J. P. MARTIN
F. E. HANCE
C. E. PEMBERTON

Associate Editors

3-7-39

ORGAN OF THE EXPERIMENT STATION OF THE HAWAIIAN SUGAR PLANTERS' ASSOCIATION

HONOLULU
1932

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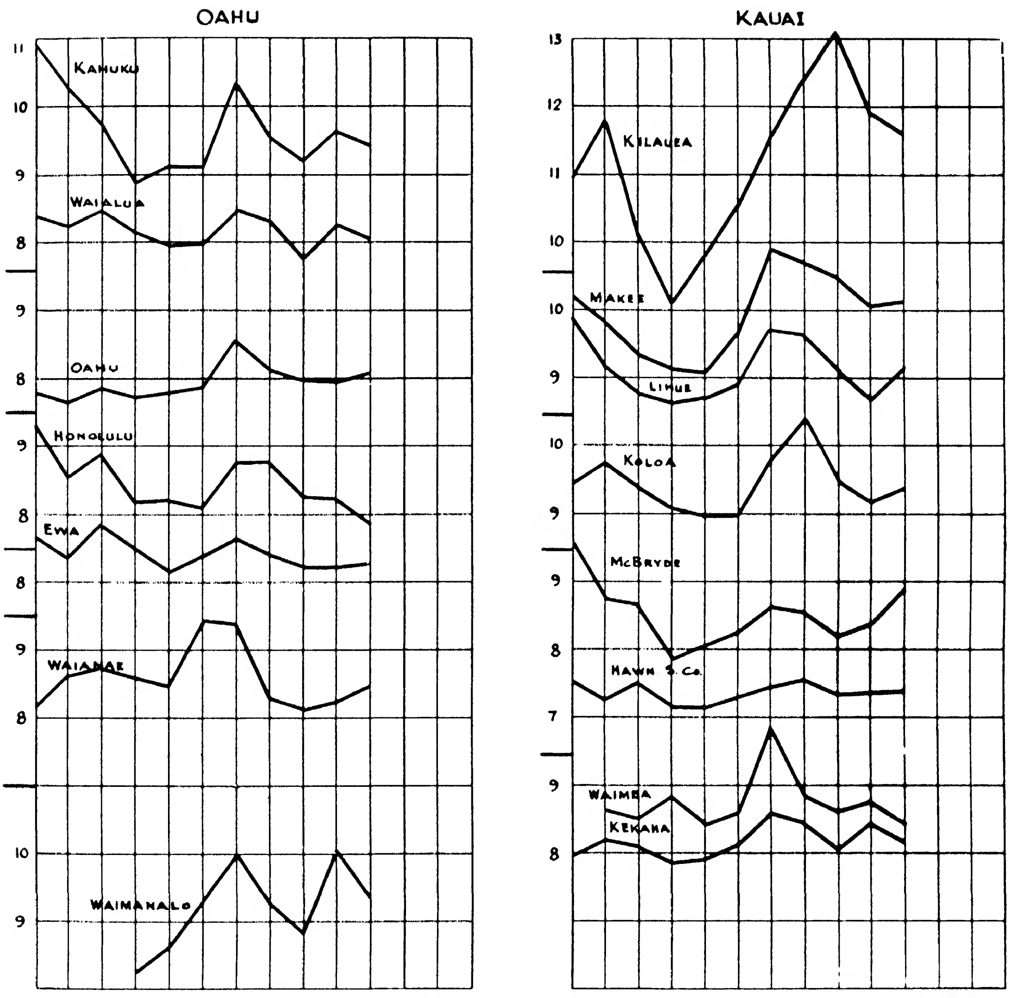
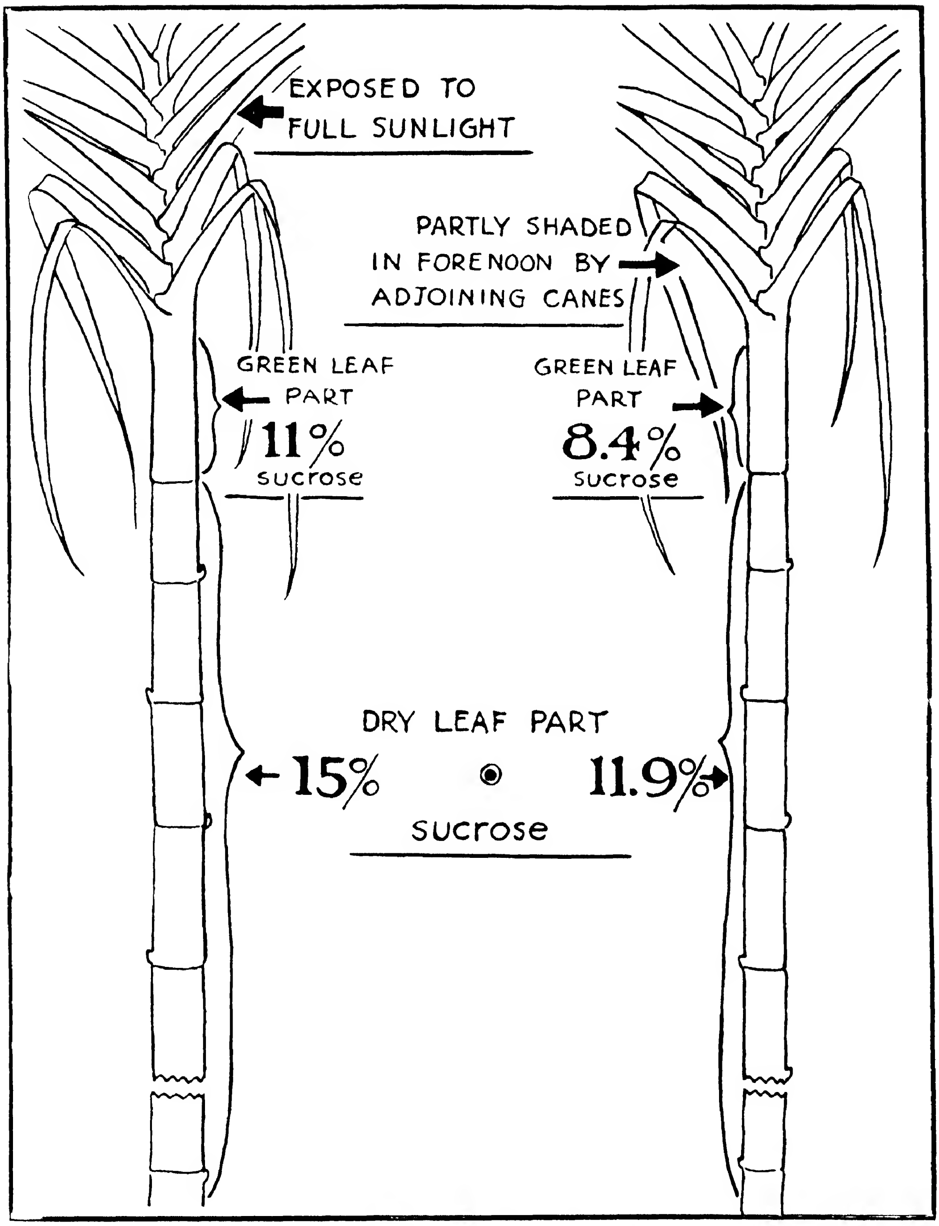
April



Data on tons of cane per ton of sugar for a ten year period, showing for different plantations similar trends of variation.

Coimbatore 290 as it appeared on the island of Molokai before being cut for distribution to the plantations.



The effect of sunlight on sugar formation in the cane stalk is here indicated.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXVI FIRST QUARTER, 1932 No. 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Dr. Walter Maxwell:

An article on the life and work of Dr. Walter Maxwell, by Dr. C. A. Browne. Dr. Maxwell was the first director of this Experiment Station. Dr. Browne is the chief of Chemical and Technological Research, Bureau of Chemistry and Soils, U. S. Department of Agriculture, Washington, D. C.

Control of the Nutgrass Armyworm With Arsenical Dusts:

An account is given by *C. E. Pemberton* of the habits and life history of the nutgrass armyworm (*Spodoptera mauritia*), and of the epidemic which occurred on the sugar plantations of Maui in 1931.

Control methods are discussed and details given for the use of arsenical dusts. From large-scale experiments on the Maui plantations, and many tests, the following mixtures are recommended for use:

Finely powdered raw rock phosphate	6 parts
White arsenic	1 part
or	
Finely powdered raw rock phosphate	5 parts
Powdered arsenate of lead	1 part

Plantation Labor:

There is a discussion of plantation labor in relation to labor saving methods and devices.

An Investigation on the Effect of Temperature on Root Absorption of Sugar Cane:

A brief account of previous work dealing with the effect of temperature on root absorption is presented. An experiment on this subject with sugar cane at

the Experiment Station is then reported. It is concluded that in water culture lowering the temperature from 80 degrees to 70 degrees, 59 degrees and 50 degrees Fahr., causes progressively greater decreases in the amount of water absorbed by the roots.

A Further Study of the Influence of Weather on Yield:

Our past studies of the influence of weather on yield were more of a qualitative nature. General conclusions were drawn but no attempt was made to obtain the quantitative relation between weather and crop production. In the present paper the cane yield and juice quality of twenty crops of the Pepeekeo Sugar Company have been mathematically analyzed. It is shown that about 80 per cent of the variation in cane yield from year to year and about 50 per cent of the variation in juice quality are associated with the conditions of temperature and rainfall. This study confirms our previous contention that weather conditions constitute one of the major factors in crop production under Pepeekeo conditions.

Filter Mud and Molasses:

Some notes are given on the use of filter mud and molasses by the plantations.

Distribution of Soil Moisture After Irrigation:

The widespread development of irrigation methods other than the standard Hawaiian contour system in the past two years has aroused increased interest in the economic application of irrigation waters. In the final analysis, the efficiency of an irrigation method must be judged by its ability to distribute soil moisture to the feeding roots of the plant.

In this issue is reported the results of a preliminary investigation on the distribution of soil moisture under the contour method of irrigation at the Waipio substation, the long line or modified orchard system at the plantation of the Waimanalo Sugar Company, and the border method at the Ewa Plantation Company.

Annual Synopsis of Mill Data:

The 1931 Annual Synopsis of Mill Data is included in this issue. The 1931 Synopsis has been published separately as Circular 58.

Dr. Walter Maxwell

By C. A. Browne

Agricultural chemists and experiment station workers whose memories date back to the period of 1890 to 1910 will be grieved to learn of the recent death of Dr. Walter Maxwell at North Conway, N. H., on July 9, 1931, after a short illness from pneumonia. The scientific career of Dr. Maxwell was of such exceptional interest that a brief mention of it should be recorded at the present time.

Dr. Walter Maxwell was born at Marsh House, Greatham, Stockton-on-Tees, Durham County, England, on June 14, 1854. His early life was spent in the country and he intended to devote his career to the management of a country estate but the great depression then existing in the agriculture of Great Britain caused him to modify his original plans. He decided, therefore, to apply himself to agricultural chemical research and after graduating from the Science Department of South Kensington, London, he proceeded to Zurich, Switzerland, where he studied agricultural and physiological chemistry under Prof. E. Schulze. After graduating from Zurich he worked first as an assistant to Professor Schulze, with whom he conducted various investigations upon the chemistry of plant cell membranes and the constituents of leguminous seeds. He then came to the United States where he took a post-graduate course at Harvard University, during the college year of 1888-1889. His research work at Harvard was devoted to investigations upon the carbohydrates, lecithins and other constituents of various leguminous seeds, such as the pea, bean and vetch. In the summer of 1889 he conducted a class in physiological chemistry at the Harvard Summer School.

On September 1, 1889, Dr. Maxwell was appointed assistant chemist in the Bureau of Chemistry of the U. S. Department of Agriculture, where he worked for the next four years under the late Dr. H. W. Wiley upon sugar making experiments. This was the beginning of his connection with an industry that was to demand so great a part of his later attention. He had charge of the federal sugar beet experiment station at Schuyler, Nebraska, and collaborated with Dr. Wiley in the preparation of four bulletins* upon "Experiments with Sugar Beets." Dr. Maxwell's reports upon work at the Schuyler Experiment Station related to the production of native sugar-beet seed, to the cultivation of the beet, to the prevention of losses from deterioration of sugar beets during storage and to other related subjects. These investigations were of a pioneer character, being among the first of the kind to be conducted in the United States. His remarks in 1893 upon the superiority of home-grown sugar-beet seed for native conditions have been confirmed by later investigators and his recommendations upon this subject are still worthy of consideration.

During his connection with the Department of Agriculture Dr. Maxwell conducted various researches upon the organic acids of sorghum juice, the nitrogenous bases in cottonseed, the biological function of the lecithins and other subjects.

* Bulletins 30, 33, 36 and 39, Division of Chemistry, U. S. Department of Agriculture.

Papers upon his scientific work at Zurich, Harvard and the U. S. Department of Agriculture were printed in the American Chemical Journal (1889 to 1893) and in other publications.

Dr. Maxwell resigned as chemist with the U. S. Department of Agriculture on November 13, 1893, in order to accept a research position at the Audubon Park Sugar Experiment Station in New Orleans, La., under the late Dr. W. C. Stubbs. During his period of service in Louisiana Dr. Maxwell published a series of important researches upon the organic non-sugars of cane juice and upon the clarification of cane juice, the results of which are contained in Bull. 38, second series, of the Louisiana Experiment Station. During this period a state of great depression existed in the cotton industry of the South and in response to a prize offer by a New Orleans newspaper for the best essay upon the means of remedying the situation Dr. Maxwell won the award of $500.00.

In 1895 when the Hawaiian Sugar Planters' Experiment Station of Honolulu was organized, Dr. Maxwell, upon the recommendation of Dr. Stubbs, was appointed its first director. During his residence in Hawaii, which was the most prolific period of his scientific career, Dr. Maxwell published numerous reports upon the work of that Hawaiian Station, and wrote various miscellaneous articles upon irrigation in Hawaii, experiments with sugar cane, the lavas and soils of the Hawaiian Islands, and other agricultural and chemical subjects. His series of articles upon the estimation of the elements of plant food, probably available in soils, by extraction with aspartic acid, attracted considerable attention. The credit of inaugurating the first extensive study upon the chemistry of Hawaiian soils is due to Dr. Maxwell.

In 1900 Dr. Maxwell resigned his position in Hawaii in order to accept the directorship of the Bureau of Agricultural Experiment Stations in Australia, where he remained for the next ten years. It was stated at the time of his appointment that the salary (£3,000) was the largest ever offered to any agricultural experiment station director in the world. During the period of his activities in Australia Dr. Maxwell published numerous reports upon the work of its experiment stations, upon cultivation and irrigation, upon the cane sugar industry of Australia, upon feeding stuffs, and various other agricultural topics. In the fifteen years of his directorship of experiment stations in Hawaii and Australia, Dr. Maxwell continued to maintain his former contact with the U. S. Department of Agriculture as special agent for supplying information upon agricultural plants and products.

Upon his resignation from the directorship of the Bureau of the Australia Agricultural Experiment Station in 1910, Dr. Maxwell was appointed a special agent of the U. S. Department of Agriculture for the purpose of studying the sugar cane industry in the Philippine Islands.

During the World War Dr. Maxwell spent much of his time in England, where he rendered distinguished service to the cause of the Allies by his expert advice upon matters pertaining to sugar and other tropical agricultural products and in other ways. It was his misfortune to lose a son at the battle front in 1916 and this bereavement with other family afflictions cast a deep shadow upon the remainder of Dr. Maxwell's life.

After the close of the war Dr. Maxwell returned to the United States, where he selected Washington as a place of residence. He spent his summers at Jackson, N. H., a place to which he was particularly devoted, and it was here, just following his seventy-seventh birthday, that he was stricken with his final illness.

In his later years, although not actively engaged in scientific pursuits, Dr. Maxwell maintained his interest in agricultural chemical research. He was fond of literature and, as a solace for the sorrows which he had suffered, began the writing of verse. In 1925 he published a small edition of "Wayside Verses," printed by Basil Blackwell of Oxford. In 1930 he published "The Master of the Voids," a philosophical poem which was privately printed by the Merrymount Press of Boston. The latter work, of which an excellent review appeared in the magazine section of the Washington Star of January 11, 1931, has attracted much favorable notice.

Dr. Maxwell was a corresponding member of the National Geographic Society of America, a Fellow of the Geological Society of Great Britain and a participant in the work of various scientific and agricultural organizations. He was also a member of the Harvard Club of Boston and the Cosmos Club of Washington.

In the period of his greatest productivity Dr. Maxwell was a most aggressive worker. He was a man of broad vision and the agricultural experiment stations which he established in Hawaii and Australia have developed into institutions of the first rank. His numerous contributions to tropical agriculture, more especially to the agriculture, chemistry and technology of the sugar cane, made him one of the best known workers in this field during the period of a generation ago.

Control of the Nutgrass Armyworm With Arsenical Dusts

By C. E. Pemberton

Extensive outbreaks of the armyworm *Spodoptera mauritia* (Boisd.) have occurred during 1931 in many parts of Hawaii. Portions of each of the main islands suffered. The damage was done both in young cane and in grasslands. Instead of subsiding, as usual, after a few generations, owing to the activity of several different parasites, succeeding broods in destructive numbers have persisted in places since the beginning of the outbreak in April and May to the present date (January, 1932). This armyworm has been most abundant on the island of Maui. Several hundred acres of young cane up to three feet in height have suffered. In portions of many fields most of the leaves were stripped to the bare midrib. In some cases succeeding generations of the armyworm kept the stools bare of foliage long enough to kill the cane. In the majority of the affected territory the cane has recovered; but there has been a distinct setback through cessation of growth for varying periods.

Under the conditions prevailing in Hawaiian cane fields, *Spodoptera mauritia* has been well named the nutgrass armyworm. Nutgrass, *Cyperus rotundus*, is the most persistent and common plant pest of many Hawaiian cane fields. It is especially troublesome on the island of Maui. In spite of almost constant warfare against this by cultural and chemical means, it quickly reappears. Many young fields become carpeted with this sedge. It furnishes an ideal food for newly hatched Spodoptera larvae. Many grasses found in our cane fields are also utilized by the young larvae, but since nutgrass greatly exceeds all other plant pests in most of the Spodoptera-injured territory it may be said to be almost solely responsible for the major outbreaks. In the absence of nutgrass, it is probable that Spodoptera would rarely be noticed, since most, if not all, of the other common grasses which the young worms feed on, can be held in check by the usual weed control methods sufficiently well to prevent large multiplication of this armyworm. This applies especially to the irrigated plantations.

Though some newly hatched Spodoptera larvae do feed on tender young cane leaves and develop to maturity without previously getting a start on grass, the percentage is small and the occurrence of destructive numbers of caterpillars in cane fields practically free of nutgrass or other grasses is not to be expected. Indoor tests with newly hatched Spodoptera larvae strikingly indicate their preference for nutgrass as against succulent cane leaves. When fed cane leaves only, very few young larvae succeed in developing. Where Spodoptera eggs have been laid in quantity in cane fields where nutgrass and other grasses are absent or have been recently removed, the mortality amongst the newly hatched larvae will be very high.

In fields of young cane, Spodoptera eggs are normally laid on the leaves near the tips. Upon hatching, the minute larvae lower themselves to the ground on fine

silken threads. Here they feed on nutgrass or other grasses for about 7 to 10 days, when large numbers of them leave the grass and crawl onto the cane. They are now about three-quarters of an inch or more in length They are conspicuous, easily seen, and their damage to the leaves soon becomes evident. They are usually on the cane from 7 to 10 days. When full-grown they drop to the ground again and pupate just beneath the surface of the soil or beneath trash, stones, lumps of earth, etc. The pupal stage occupies from one to two weeks, when the moths hatch out to start another brood. Their egg-masses can again be seen on the cane leaves.

From the rough summary above it is seen that there are four distinct phases in the life history of this moth, all easily recognized (see chart). First the egg-masses are prominently visible on the cane leaves. Secondly, myriads of young armyworms have appeared on the nutgrass, or other grass if present. Thirdly, quantities of these worms, of good size, are on the cane, and in the final, fourth, phase, they have disappeared underground and have pupated. These four stages are clear cut with very little overlapping of broods in any particular field or sometimes over the whole plantation. This, fortunately, permits effective control by poisoning the insect, particularly in the second phase of its development, when it is confined to the grass and is not yet on the cane.

Arsenical dusts are by far the simplest, cheapest and most effective forms of poison for this armyworm. Dusts can be applied rapidly and efficiently by hand, requiring no machinery, no special procedure in the mixing of the ingredients, and can be transported from the warehouse to any desired spot on a plantation at a moment's notice ready for immediate use. The mixture once made can be held in readiness under cover for an indefinite period.

After many tests the following mixtures are recommended and can be depended upon to give complete satisfaction if no rain follows within 24 to 48 hours after application:

Finely powdered raw rock phosphate	6 parts
White arsenic	1 part
or	
Finely powdered raw rock phosphate	5 parts
Powdered arsenate of lead	1 part

Proportions by weight.

At present prices the commercial white arsenic is obtainable at about one-third the cost of powdered arsenate of lead in Honolulu. Since white arsenic is regularly imported in quantity into the Territory for making the standard sodium arsenite weed killer, it has the additional advantage in being immediately available in any desired amount at all times to all plantations. It is practically insoluble in water and makes an effective dust if combined with an inert substance like powdered raw rock phosphate or finely powdered gypsum.

Raw rock phosphate, when finely ground, is slightly preferable to gypsum as a carrier for the arsenic. Being a commonly used commercial fertilizer, it is always available in quantity. It was first used at Wailuku Sugar Company, with excellent results.


STAGE 1
The Moth lays its eggs
on the cane leaf.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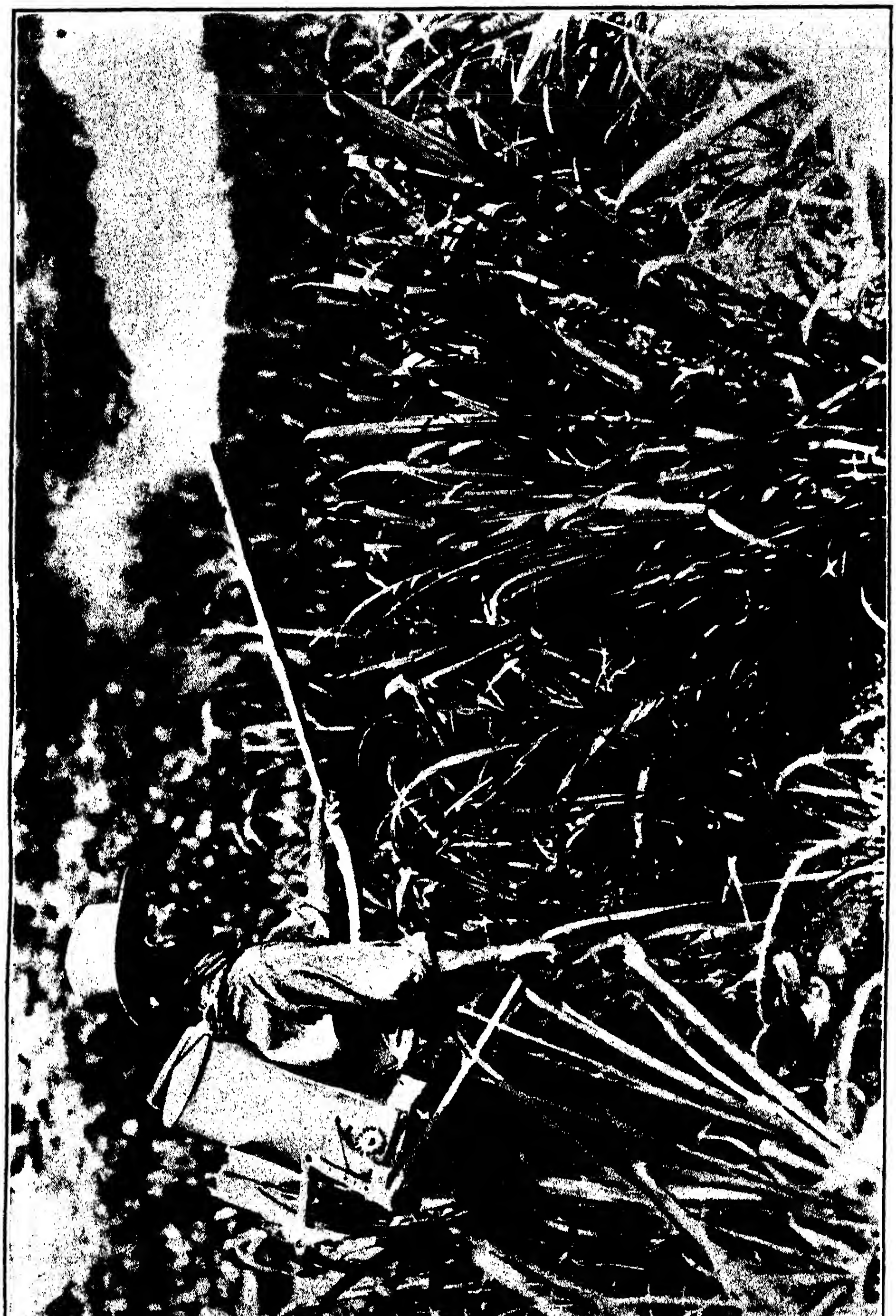
Application of poison dust by sifting from a bag.



Dusting with an American Beauty Duster.

Lime should never be used in combination with white arsenic. It is injurious both to the workers and to the cane. The following memorandum from Dr. F. E. Hance, chemist of this Experiment Station, on the subject is of interest:

> When calcium hydroxide (slaked lime) is added to white arsenic and the mixture becomes moistened or damp reaction sets in which tends to produce soluble arsenite in the vicinity where the dust may settle. If this dust is inhaled by the operator of the outfit, soluble arsenic may be absorbed by the system. If this same dust settles on a cane leaf, when that leaf becomes wet, it probably will suffer just as though it had been sprayed with common arsenic weed spray.

A negligible amount of burning appears on some of the cane leaves when moistened by dew or rain after dusting with white arsenic and raw rock phosphate. It has not been serious and is of no importance considering the benefits derived through the immediate suppression of the feeding armyworms. No burning whatever follows the use of lead arsenate dust in combination with raw rock phosphate or gypsum.

Since powdered arsenate of lead is much lighter than white arsenic and more finely divided, it mixes more uniformly with raw rock phosphate or gypsum and has better adhering qualities also. These advantages are offset, however, by the cheapness of white arsenic and from the fact that in field practice white arsenic accomplished the end sought when mixed with the carrier in such a strong ratio as 1:6, even without the addition of sticking ingredients. Weaker mixtures of white arsenic and raw rock phosphate have been used with success. One part white arsenic to 7, 8 and 10 parts of raw rock phosphate, respectively, have been used with good results; but the 1 to 6 mixture is safer to use owing to variations in the purity of commercial white arsenic and to the difficulty of securing a uniform distribution of the arsenic in the mixture. When the distribution is not entirely uniform the amount of arsenic at times dusted out from a weak mixture would not be sufficient to kill. The 1 to 6 mixture also kills quicker than the weaker preparations and consequently a more certain success follows in case of an early rain after dusting.

The mixing of the ingredients of the above recommended dusts can be satisfactorily done by simply hoeing or raking together the proper weights of each on a solid floor or in a wooden bin. It should be done thoroughly. The workmen should wear dust masks over the mouth and nose while mixing the poison. It has not been found necessary to wear masks in the field when applying the dust. It would be advisable, however, to encourage the use of such masks in the field, especially when men may be applying dust for a week or more continuously. Workers will occasionally develop a mild rash on chafed or scratched areas after dusting for several days. No disturbing results have attended this excepting when lime was first used as a carrier for the arsenic.

For best results the dust should be applied during the second phase of development of the caterpillars. This, as mentioned above, is that period when the larvae are on the grass and are yet too young to have moved onto the cane. With a reasonable amount of observation and experience in the field this period can be easily recognized by field men. A thorough dusting of the grass over the entire

floor of the affected area can be easily accomplished and the young cane entirely saved from damage.

It is useless to apply dust when rain is falling. Should rain fall within 24 hours after dusting it is best to repeat the operation.

If dust is not applied until the caterpillars are upon the cane then both the cane and grass should be dusted.

More than one dusting may be necessary, the succeeding applications occurring about 2 or 3 weeks apart. This becomes necessary when moths fly in from adjacent untreated territory and place their eggs on the cane.

As soon as the cane starts closing in and the grass becomes shaded and less abundant, there is little danger of further armyworm damage within the field. Along grassy watercourses, in fallow fields, and large unshaded irrigation ditches where there is plenty of grass, outbreaks may continue and maturing larvae may crawl from the grass to the large cane and feed; but this damage will only border such open spaces and not penetrate into the field away from the watercourses, ditches, etc. Such places are easily accessible for dusting operations.

Dusts have been applied very satisfactorily in the manner shown in the accompanying illustrations. The poison can be very rapidly spread with a bag. About 25 pounds of the mixture is placed in a sugar bag or flour sack at a time. The bag is held horizontally, as indicated, and rocked by alternately raising and lowering each hand. The mixture, thus agitated, sifts out through the cloth as a fine cloud of dust. The amount of dust let out can be easily regulated by the degree to which the bag is agitated. Usually a sufficient amount of dust is applied by the operator when walking at normal speed if the bag is constantly agitated. This method has shown particular merit in the dusting work at Pioneer Mill Company, Ltd.

The mechanical duster here shown also applies a uniform cloud of dust and is especially useful in directing dust against worms which have crawled well up on cane 3 or 4 feet high. There is very little waste of material when using the mechanical duster. It is somewhat slower in operation than by the bag method, but has given excellent results where used. It is light and easy to operate. Since the dust is discharged from a nozzle held well away from the operator, very little annoyance results from excessive dust about the head or over the body.

The cost for materials and labor should not exceed $3 per acre for one treatment. This will vary depending upon the density of the grass and the age of the cane. When a field is dusted before the worms have left the grass for the cane the cost should be less than the above figure.

Fig. 1. A forester's trail into a Malay jungle.

SCENES IN A MALAY JUNGLE

A jungle is a blanket of vegetation in which all available space is occupied by some form or other of plant life. The Malay States contain some of the finest examples of jungles to be found anywhere in the world. They have great vertical depth because they include many species of trees that attain great heights and they are dense because they include an enormous variety of plants, some adapted to

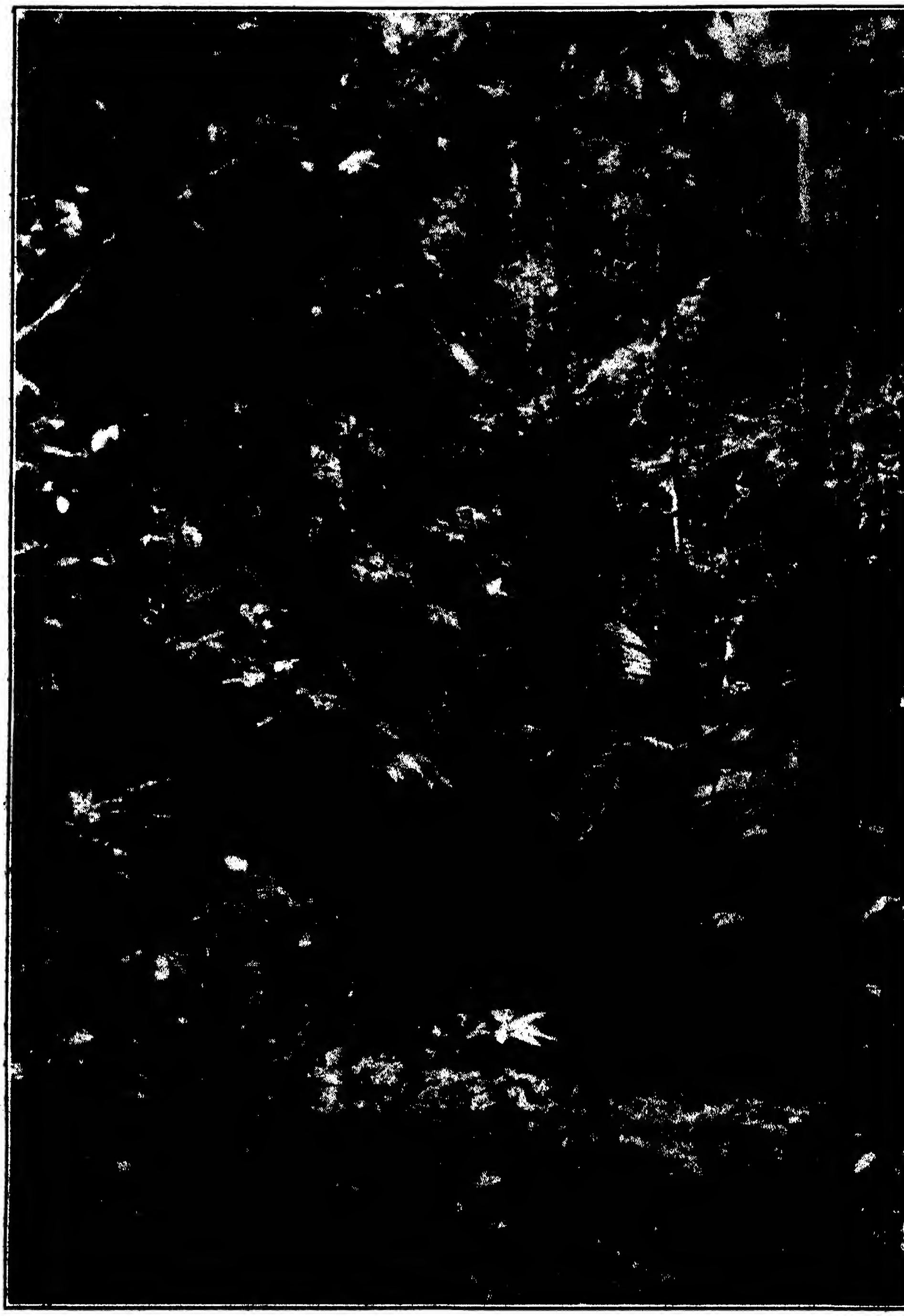


Fig. 2. Along the edge of the trail.

grow under each and every condition that the jungle affords. There is first a ground cover composed of small ferns and herbs. Above this comes a second story, occupied by the crowns of shrubs, gingers, small palms and tall-growing ferns; in the third story we find the crowns of taller-growing shrubs and palms and then above this may be distinguished story after story until we get to the very top, which is occupied by the crowns of the tallest-growing trees.

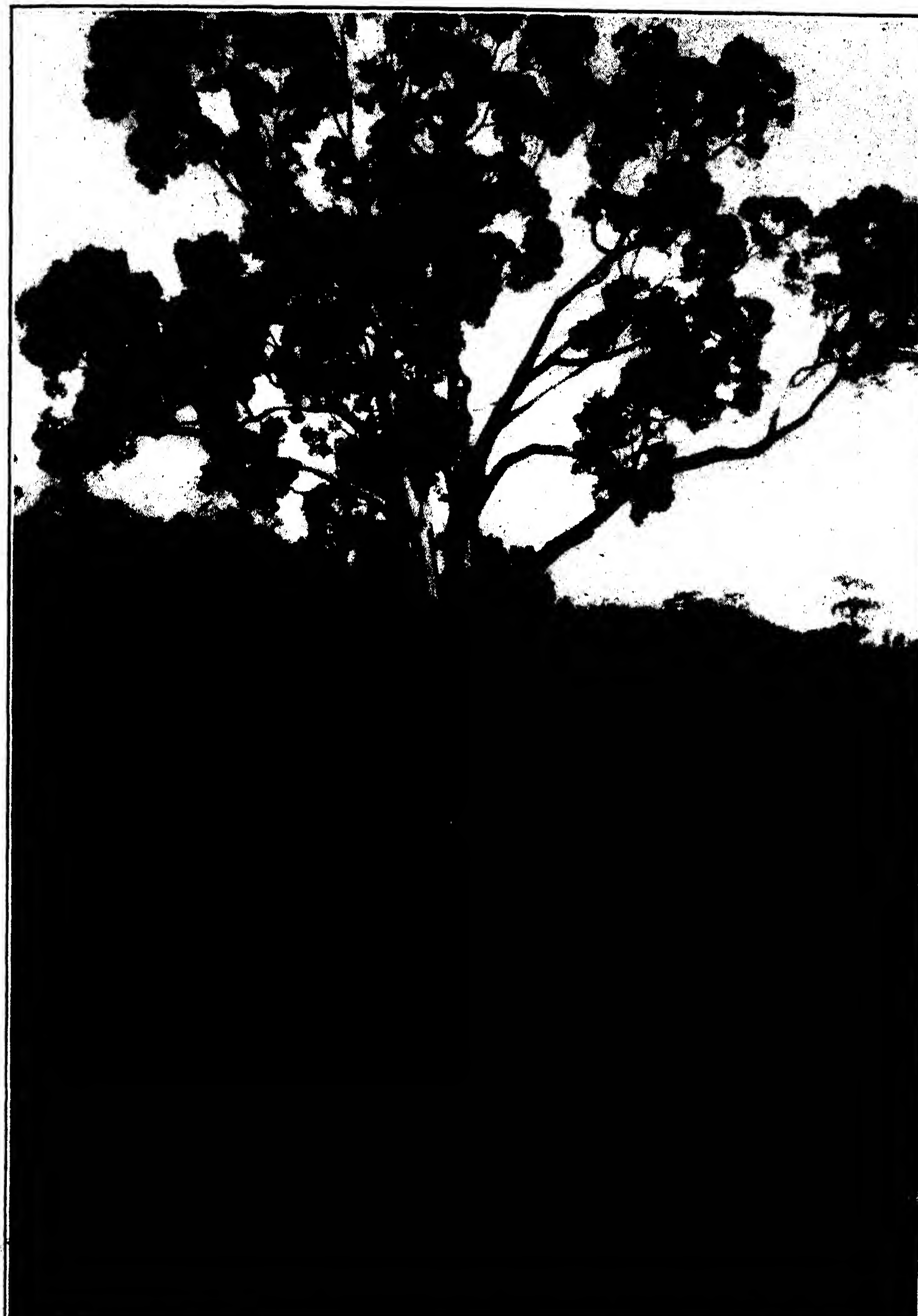


Fig. 3. A huge "Meranti" tree in a forest clearing.

In anticipating the structure of such a jungle, one might expect to find huge trees standing close together throughout the jungle, but this is rarely the case, the huge trees usually standing well apart, the intervening spaces being occupied by more slender trees, the crowns of which may reach as high as those of the trees with largest trunks. In such a jungle, the majority of the tallest-growing trees must start up as seedlings from the forest floor and grow up through the successive

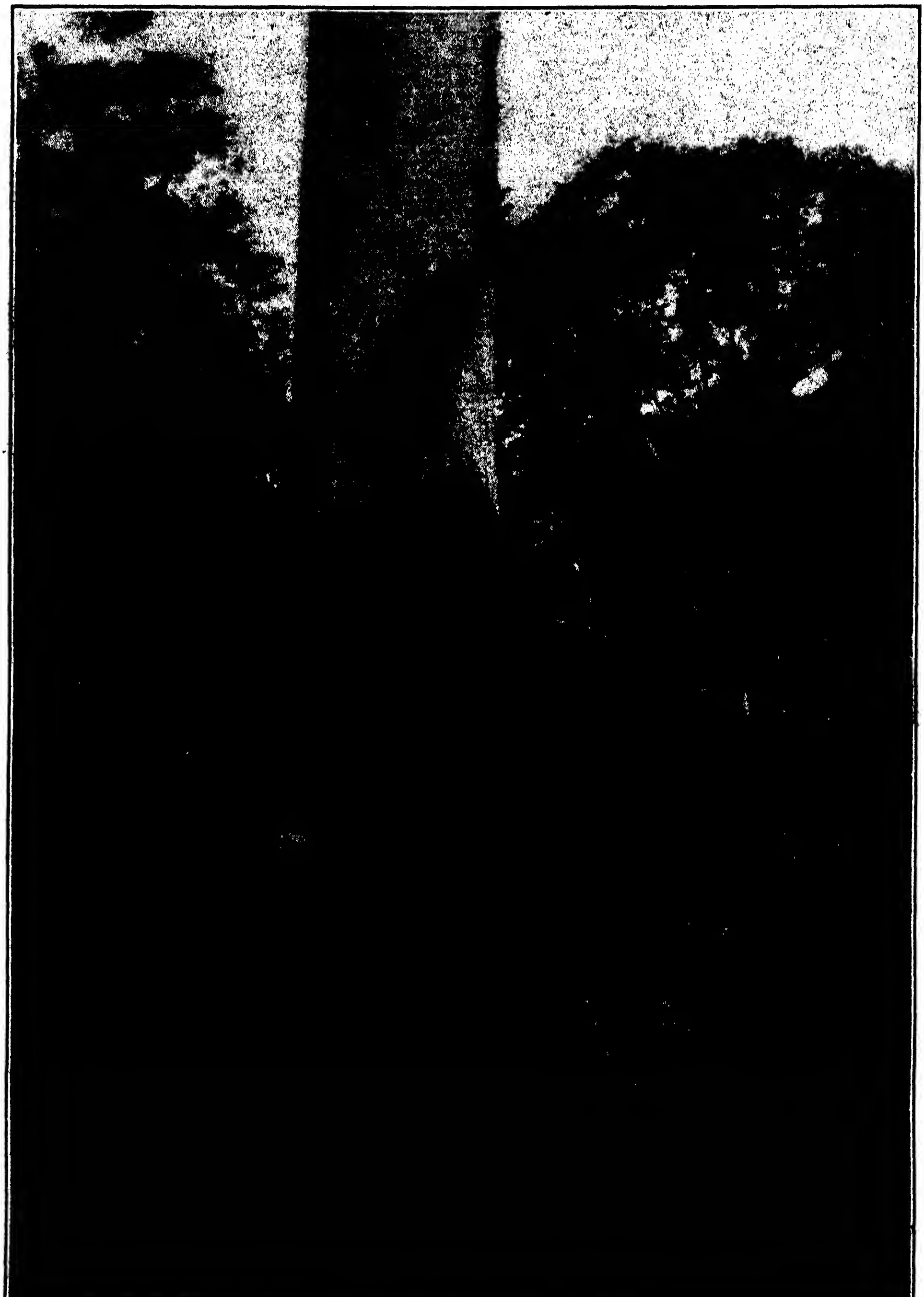


Fig. 4. Butt of the "Meranti" tree shown in Fig. 3.

stories until they reach the top. These tallest-growing trees usually push their crowns up rapidly, supporting them on a slender trunk until they reach great height, after which the trunk thickens up, so in a jungle we often find a preponderance of slender trunks, with only an occasional huge trunk.

Vines of many kinds are conspicuous features of the Malay jungle. Like the shrubs and trees, they grow in great variety and sizes. There are some which are

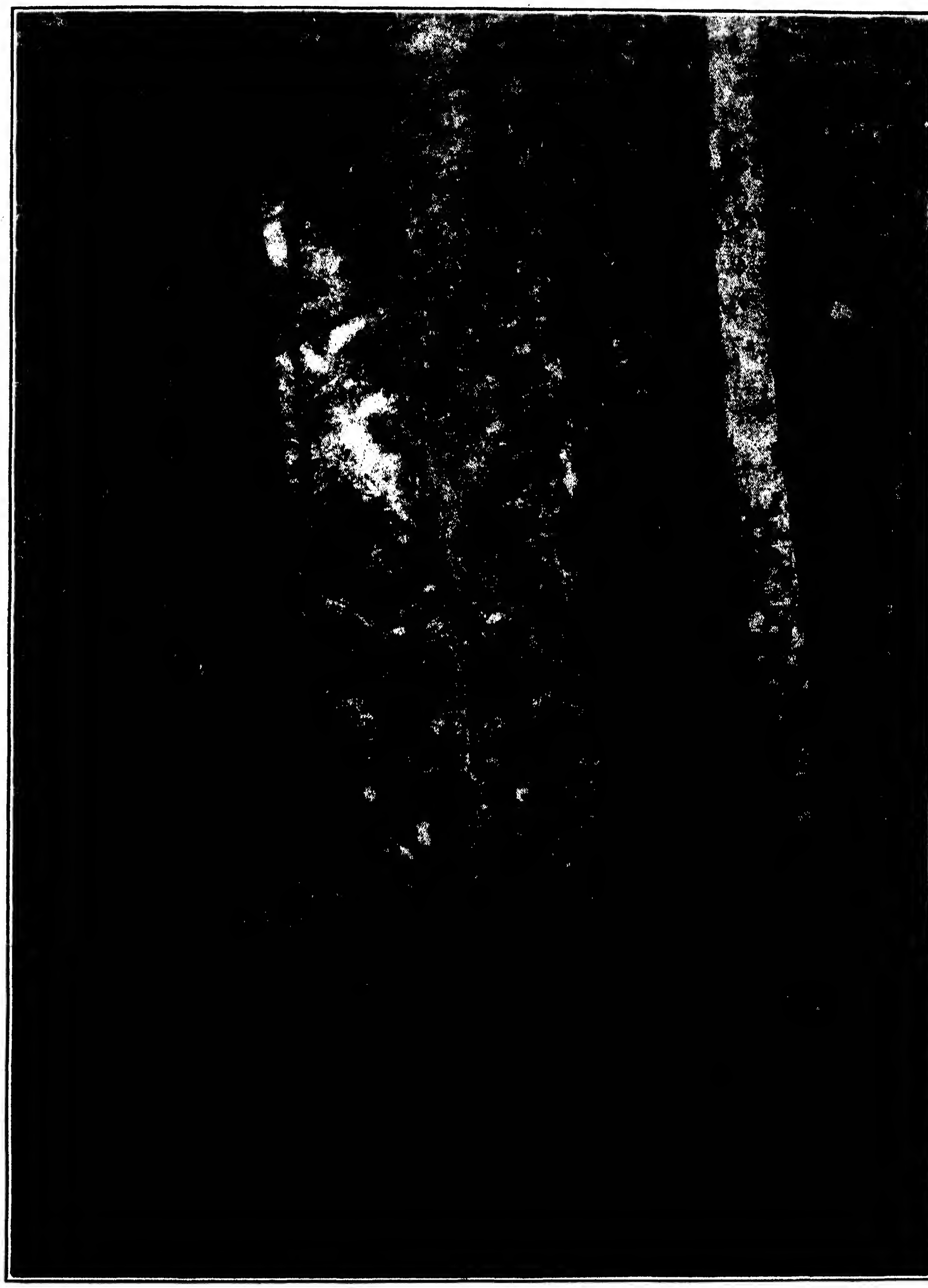


Fig. 5. Twisted stem of a woody vine.

tiny and low growing, while the giants in this class are mighty liana with woody, twisted trunks up to a foot or more in diameter, which climb to the very tops of the tallest trees and then extend their sprawling branches for great distances. Many of the more pleasing vines to be met with are the climbing aroids, plants of the taro family, which have fleshy leaves artistically shaped and cut.

Palms constitute a conspicuous feature in the Malay jungle and appear in a great variety of sizes and shapes. The very common Bertam palm never raises its

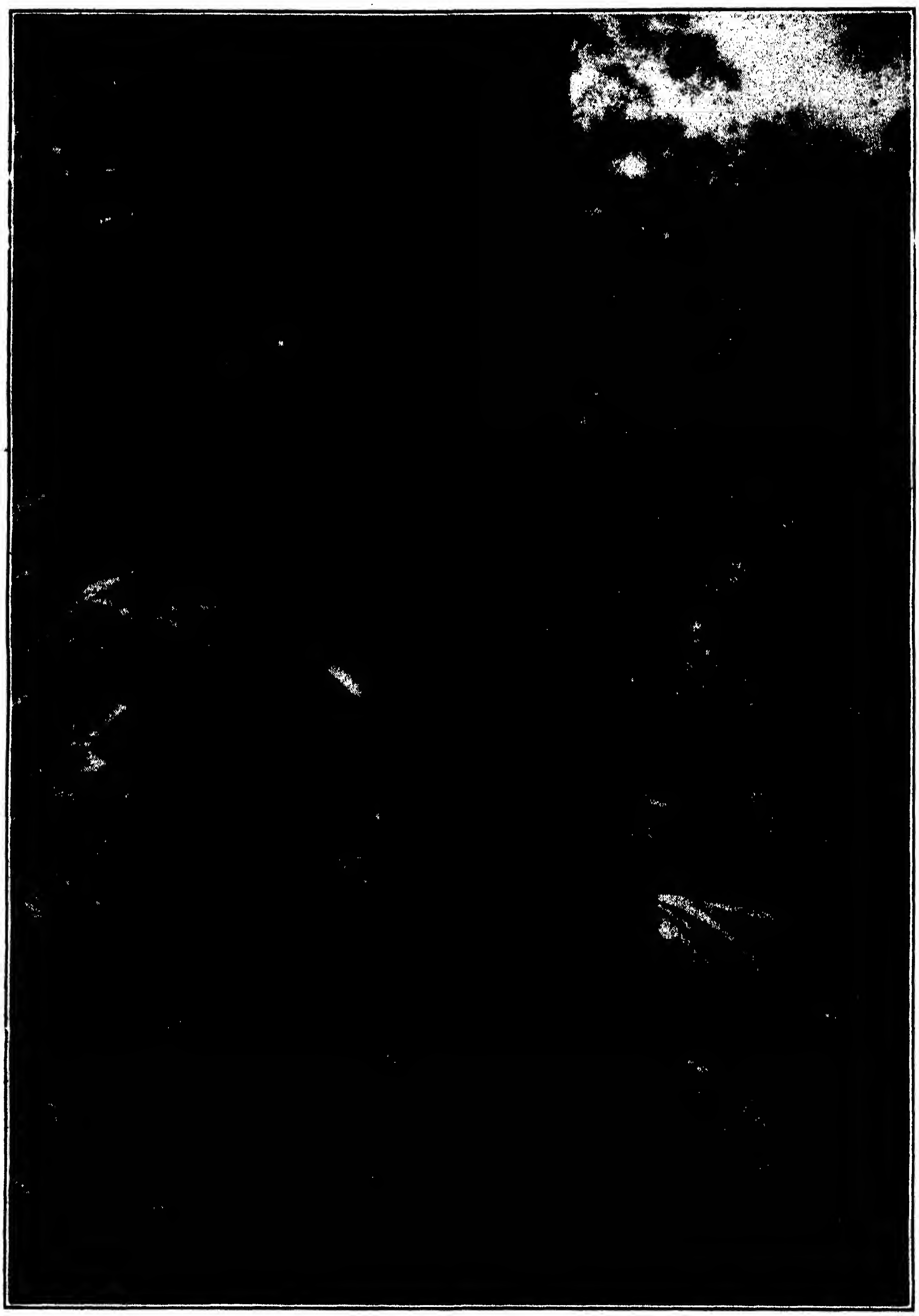


Fig. 6. A climbing fig flanked by two aroids.

trunk far above the surface of the ground but produces a dense crown of leaves which are ornamented with an abundance of long, sharp thorns. Then there are the handsome, tall-growing "Nibong" palms, a group of which is shown in Fig. 7. Other palms of frequent occurrence which can give you much trouble are the rattans. These are climbing palms with very slender stems bearing long leaves well supplied with sharp hooks by means of which the plant hangs on to the stems

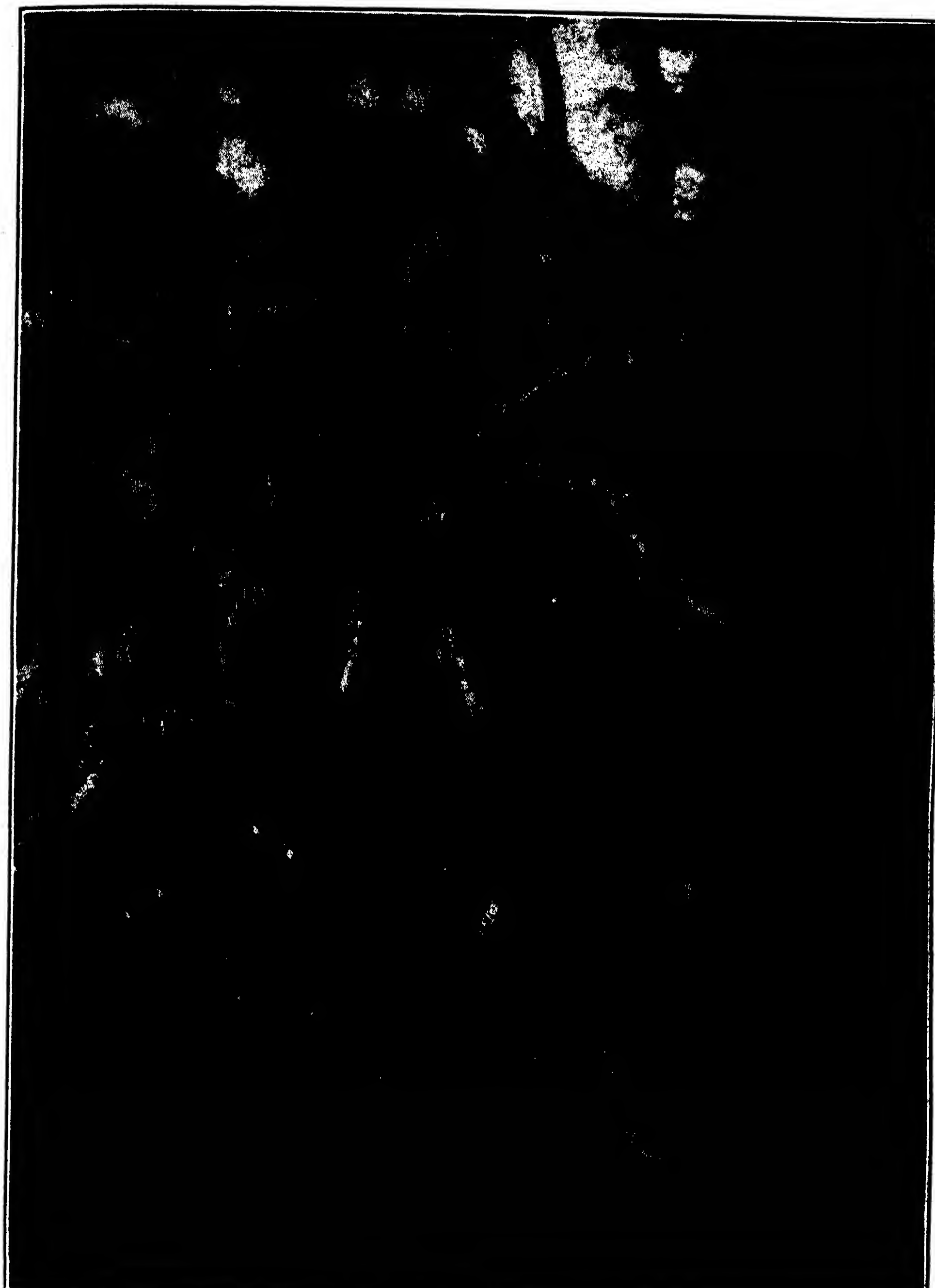


Fig. 7. A clump of thorny palms, "Nibong."

and branches of the trees as it pulls its crown up through the successive stories of the jungle. The most pleasing palms are the shade-loving ones such as may be seen in Fig. 8. These palms never attain very great height. Their slender trunks are unarmed and make exceptionally fine walking sticks. When dry, they are extremely light but surprisingly strong and durable.

Another class of attractive plants growing in the Malay jungle are the perch-

Fig. 8. A shade-loving palm, "Pinang."

ing plants which live on the trunks or branches of the trees and have no connection of their own with the soil. Among these are many orchids, some with very handsome flowers. Numerous perching ferns and aroids are also to be found but the most remarkable perching plant seen was a bright-flowered ginger which establishes itself high up in a tree, wrapping its fleshy roots into a ball around a branch.

—*Notes by H. L. Lyon. Photographs by C. E. Pemberton.*

Man-Day Performance in Relation to Agricultural Methods and Implements*

By L. D. Larsen

A man with a hoe does a given amount of work. This may be increased materially by special inducements. Piece work, which caters to his pocketbook, is perhaps the commonest means of increasing his labor performance. Competition, which appeals to pride and accomplishment, is also used to bring out more work. Special rewards and honors also accomplish the same thing.

Some interesting developments along this line have taken place in recent years whereby labor performance has been stepped up very materially. Most outstanding examples of this have taken place in the harvesting field, especially with cutting cane. The rate of fertilizing and hoeing has also been increased materially by these means.

This type of development may be considered true man-power development. It embodies elements of psychology and leadership and should prove a most profitable subject for investigation. For the purpose of this paper, however, we shall omit this type of development and confine ourselves to indirect man-power development brought about by the use of better tools, more power, or changed cultural methods.

Not so many years ago plowing in the Islands was done largely with bullocks and with mules. The steam plow replaced animals for this operation to a large extent, and the tractor in turn replaced the steam plow.

Those of us who went to Java two years ago were shocked to find that plowing was still done by man-power and a spade, fertilizer was applied with a spoon, and irrigation water with a bucket.

Only a few years hence we shall look back on the primitive days when planting in the Islands was done by hand, when water was applied in small streams to a 30-foot furrow, while the laborer stood watching it run, when weeds were controlled largely by the hoe, and when fertilizer was carried over the field on a man's shoulder and applied by hand.

The total labor on our plantations is divided, occupationally, about as follows:

Agricultural labor	35 per cent
Harvesting labor	25 per cent
Factory labor	10 per cent
Sundry labor	30 per cent

In our present study we shall consider agricultural labor only, leaving harvesting, factory, and sundry labor for future consideration.

While 35 per cent of the total labor is employed at agricultural field work, this percentage increases during portions of the year to over 50 per cent. The specific operations on which this 35 per cent or 50 per cent is employed may be divided

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roughly into (1) preparing and planting, (2) cultivation and weed control, (3) irrigating, and (4) fertilizing.

While a study of these four operations would cover the field of this paper almost completely, there are related factors which influence the situation and which should not be lost sight of. Varieties of cane, for example, have a bearing on labor performance and on labor requirement. Time of harvesting is also a contributing factor.

The following list of subheadings, while dealing mainly with the four operations involved, also touch to a limited extent on certain other contributing factors:

1. Planting machines.
2. Walking vs. riding cultural implements.
3. Mules vs. motor power.
4. Light vs. heavy weeds.
5. Chemical weed control.
6. Irrigation methods.
7. Varieties of cane.
8. Harvesting season.
9. Relation between agricultural labor and total labor.

Planting Machines

Planting machines were first used in the Territory in 1922 and since that time have developed along lines of increasing labor economy. As an average achievement we would estimate an increase of some 300 per cent in man-day performance by the use of planting machines over hand planting.

In a report to the Labor Saving Devices Committee of the H. S. P. A. this year, A. T. Spalding, of Honomu, reports a reduction of from 3.9 man-days per acre for hand planting, to 1.5 man-days per acre for machine planting on his first trial with the machine, and he feels certain that this can be reduced to 1 man-day per acre in the next field, when stops for adjustment and other preliminary work with the machine will be unnecessary. This is under non-irrigated conditions.

George Chalmers, Jr., manager of Waimanalo Sugar Company, in the same report, submits actual field data showing a reduction from 12.95 man-days per acre to 3.6 man-days per acre for planting and first irrigation by the use of the planting machine together with straight-line irrigation.

Ewa Plantation Company reported 20 acres per day with a 4-row machine using 12 men. Honolulu Plantation Company reports 6 acres per day with a small 2-row machine and 6 men.

From the above it would seem quite in order to estimate a 300 per cent increase in labor performance by the use of planting machines. A striking reduction in cost is also shown by these places, but for the purposes of this paper we are omitting cost statistics.

Walking vs. Riding Implements

For inter-row cultural work and weed control mules have long been used in the Islands to increase a man's labor performance. In utilizing mules, however, there

are large discrepancies in labor performance, due to the tools or implements used with the mules, and a study of implements may be more helpful to a plantation than purchasing more mules.

R. M. Allen, manager of Kilauea Sugar Plantation Company, submits a statement showing actual performance for all cultivation work at Kilauea for the past year. This table shows an average of 5.55 acres per man-day for riding cultivators, as against 2.67 as an average for walking cultivators. For the unirrigated area riding cultivators averaged 7.68 acres per man-day.

Mr. Spalding, in submitting a report to the Labor Saving Devices Committee on a new two-row Planet Junior cultivator, reports 6 acres per man-day under non-irrigated conditions.

Mr. Chalmers, with a riding cultivator, under straight-line irrigated conditions, reports an average of 4.10 acres per man-day.

A summary of these reports would indicate an increased performance of at least 100 per cent per man-day by the use of riding cultivators over walking cultivators using mule power. Under less intensive supervision we believe the difference would be greater, since the tendency with walking implements is to stop for a rest at the end of the row and in out-of-the-way spots, while a man riding on an implement is willing to keep going.

The writer once watched a riding cultivator working alongside two walking cultivators in some rather tall cane and fairly short lines, and without an overseer. On several counts that were made unbeknown to the drivers, the riding cultivator with two horses and one man would go four times up and down the lines while the walking implements went once.

The chief reason for the almost universal use of walking implements in these Islands, the writer believes, is mental inertia. A riding implement must be adjusted and watched and can only be used to advantage at an early stage of the weed growth. A walking cultivator can be used at any time and under most any conditions.

The writer has found it extremely difficult to accustom plantation overseers to the use of riding mule-drawn implements. The stable boss, the field overseer, and the section luna are alike in this respect. With the slightest let-up of pressure or specific instruction, they revert immediately to walking implements. They have always used them and know they will do the job with a minimum of mental effort. They have been trained to think in terms of a job to be done and not in terms of man-day performance or expense.

Mules vs. Motor Power

As in the case of mules, the performance with tractor power seems to depend largely on the implement used. According to Mr. Allen's figures, a small tractor with men walking behind holding individual walking cultivators seems to be no more economical of man power than a walking mule-drawn cultivator. It would appear, therefore, that mule power may be fully as economical as tractor power *per se.* The chief factor in favor of tractor power in the field seems to be the fact

that it is more adaptable for handling larger implements and that it is possible by this means for each man to utilize more units of power.

The following statistics, submitted by Mr. Allen, give a summary of all cultivation work on that plantation for the past year. They show performance and cost for different types of implements used, comparing walking, mule-drawn riding, and tractor-drawn implements.

Implement	Acres per Unit	Acres per Man Day	Cost per Acre
Fordson pulling 3-9 tooth cultivators, 4 men in unit, 3 of them holding cultivator	8.60	2.15	1.44
Two-row riding cultivator, 1 man, 2 mules	5.55	5.55	0.68
Walking cultivator, 1 man, 1 mule	2.67	2.67	1.34
Riding disk cultivator, 1 man, 4 mules	4.26	4.26	0.87
Rotary hoe, Fordson and 1 man	4.04	4.04	1.72
Canoe plow, 1 man and 1 mule	3.37	3.37	0.80
Subsoiling ratoons, one 2-ton tractor, and 3 men	8.38	2.80	1.50
Farnall with 3-row cultivator, (1 field only)	20.00	20.00	.25

There is considerable difference in the performance of any implement in irrigated and unirrigated lands, due mainly to the time consumed in crossing the level ditches in the irrigated lands.

The following table shows the average performance of our various implements under unirrigated conditions only:

Riding cultivator, 1 man, 2 mules	7.68	7.68	0.46
Riding disk cultivator, 1 man, 2 mules	6.00	6.00	0.59

In computing the above costs, the following values were assumed:

20 HP Caterpillar day	$ 6.00	
Fordson day	5.00	
Man-day	1.75	
Mule-day	.90	$13.65

Cultivating with a two-row high clearance 10 caterpillar, Mr. Chalmers reports 12.8 acres per man-day. With a 30 Best two-row cultivator, J. M .Ross, of Hakalau, reports 16 acres per man-day. John T. Moir, Jr., of Koloa, cultivating with a 3-row Massey-Harris 4-wheel-drive tractor reports 20 acres per man-day under favorable conditions.

A study of these figures would indicate that a riding cultivator performs about twice as much work per man-day as a walking cultivator; a small direct-attached 2-row tractor cultivator will do twice as much as a riding cultivator; a 3-row direct-attached tractor cultivator will do half as much again. Thus in the evolution between a walking cultivator and certain types of tractor cultivators now in use, a man's labor performance may be increased from 2½ to 20 acres per day, or 800 per cent.

There are cases where riding cultivators are not feasible, and others where tractor implements are not desirable. Our aim therefore should not be to eliminate the mule or the walking type of implements but to utilize the faster and cheaper types of implements whenever possible. It is often claimed that tractor imple-

ments are not feasible under wet weather conditions, and we have seen cases where this type of implement has been abandoned for this cause alone. In other cases, however, it has been found that so much more area can be covered during suitable weather by the use of tractor implements that cultivation during wet weather becomes unnecessary. From an agricultural point of view it is also probable that when soil conditions are too wet for working tractors, any or all implements would be kept out of the field to advantage.

Another factor bearing on the use of power-drawn implements is the labor personnel. With the island-born laborer, who is becoming of increasing importance on our plantations, handling a tractor-drawn implement seems to be a much more desirable occupation than walking behind a mule. It seems rather important that we begin catering more to this type of labor and there is perhaps no field more promising in this respect than mechanizing the agricultural work.

Cultivation in Light vs. Heavy Weeds

One of the chief requisites for economical weed control by riding and tractor-drawn implements is to get the weeds young. It is usual in these Islands, where we are accustomed to the walking mule-drawn cultivator, to wait for the weeds to attain a husky size before attempting to eliminate them. One feels then that something is being accomplished by the effort and it is customary to go back and forth over the lines as many times as may seem necessary. Mr. Allen, in his report to the Labor Saving Devices Committee, submits some interesting data pertaining to this point:

Too much stress cannot be laid on the economy of cultivating while the grass is small. If the field is allowed to go until the grass is big it is necessary to run 3, 4 or even 6 times a line and the costs consequently increase tremendously. The following data illustrate this point:

Implement	Acres per Man-day	Cost per Acre	Remarks
Walking cultivator, 1 man, 1 mule	2.39	1.11	Light grass; once a line.
Walking cultivator, 1 man, 1 mule	0.99	2.68	Heavy grass; 2-3 times per line.
Walking cultivator, 1 man, 1 mule	0.54	4.97	Very heavy grass; 5-6 times per line.

It can readily be seen that frequent light cultivations should be practiced.

The Horner harrow, which is the leading cultivation equipment used on the wet, unirrigated plantations, was designed on a presumption of heavy weed growth and more especially honohono. It gathers the weeds into piles where a majority of them are covered and choked out. This type of cultivation results in numerous piles of dirt and weeds at short intervals in the field. These piles interfere seriously with riding and tractor implements and must be eliminated before efficient work of this kind can be attempted. Whether or not this type of cultivation can be eliminated and the honohono kept young enough for riding implements

remains to be seen. An interesting observation along this line comes from Mr. Ross in writing about a 2-row cultivator built on a 30 Best tractor at Hakalau:

> The possibilities of this cultivator are such that we look forward to dispensing with all Horner cultivators and it is possible that with the present clearance of the tractor we can get all our fields so well cleaned up with this cultivator that we can have all our cultivation finished before the cane gets so high as to prevent the 30 working in it longer.

If Mr. Ross's hopes materialize it will be a big step toward eliminating the heavy weed system of culture that has been common in the unirrigated districts.

Chemical Weed Control

Since a special paper on this subject will be presented at this meeting we shall not go into details. Suffice it to say that statistics obtained by the writer would indicate an increased labor performance of several hundred per cent by the use of poison sprays. From the point of total expense there are cases where the superiority of poisoning over hoeing is questioned. From the point of labor economy, however, the question is hardly debatable.

Mr. Allen submits figures on a very grassy field which required a total of 1.90 man-days per acre to spray at a total cost of $4.35 per acre. He estimates that to hoe this field would have required 7 or 8 men per acre.

In light grass where hoeing is easier the difference in favor of spraying becomes less and there is a point where the economy of spraying becomes debatable. Where implements can be handled to advantage the economy of spraying from a labor performance point of view is also questionable. However, with spraying as with implement work the labor performance varies with the implement used. Most statistics available at present refer to knapsack spraying. Olaa with its sled spraying shows a somewhat better performance. Mr. Maze, of the Labor Saving Devices Committee, recently developed a mule-drawn sprayer which shows promise of increasing the labor performance several hundred per cent over the knapsack. A pack-saddle sprayer has also been developed which may add materially to man-day performance in spraying.

Irrigation Methods

The greatest development along the lines of increased labor performance in recent years has been brought about by changes in methods of irrigation and the accompanying changes in field layout.

The standard performance in the Islands with contour irrigation has been approximately 1 acre per man-day. The modified orchard system which has been in use at Kilauea for some 10 years increased this for Kilauea to an average of nearly 7 acres per man-day. Under favorable conditions this has been brought up to 15 acres or more per man-day. By the border system Ewa Plantation Company has attained an average performance of 8.4 acres per man-day and a maximum of 37 acres. At Wailuku their controlled cut-line system gives an average of 6 to 9 acres per man-day, and under favorable conditions will run 12 acres per day. The Koloa system averages around 2½ acres per day, and runs up to

4 or even 5 acres under favorable conditions. The increase shown by these systems varies between 250 and 1000 per cent or more.

Closely connected and essentially a part of these new irrigation systems is the field layout, which in turn has a bearing on other field operations.

The border system devised at Ewa and the modified orchard system of Kilauea both involve parallel line planting, which in turn expedites other field operations from planting to harvesting. At Kilauea this factor is far more responsible for the labor performance than is irrigation. While irrigation alone has been reduced to less than 3 man-days per acre per crop (on irrigated fields) the total number of men affected by this is far less than the total reduction involved through planting, cultivating, fertilizing, etc. Thus, although we refer to these new systems as irrigation systems, they involve changes resulting in increased labor performance in practically every cultural operation.

Varieties

Varieties of cane have a direct bearing on labor performance and labor requirements. In the harvesting field this is recognized to the extent that different cutting rates are paid for different varieties.

In the cultural work necessary in bringing cane to maturity the variety is an essential factor and with the possibility of future labor shortage, this subject should be given more consideration than has been the case in the past. The Uba or wild blooded types are undoubtedly the easiest of all our varieties when it comes to agricultural labor. Conditions may arise when a considerable amount of yield can profitably be sacrificed for the sake of labor economy. It is not certain, however, that a sacrifice of yield will be necessary in the use of these quicker growing cane types. The eminently successful Java canes contain this blood and it seems most probable that in the many new seedlings of this type that are at present being propagated in the Islands some will be found that can close in with a minimum of labor requirement without sacrificing yield.

Harvesting Season

Perhaps the principal drawback to increased labor performance in the Islands is the prevalent oversupply of labor in the off-season. Where a long off-season occurs we all know the difficulty experienced in keeping the labor busy. Work must be saved for the off-season. Under this condition interest in increased labor performance tends to lag. Reducing field labor by 300 per cent and putting the same amount into unnecessary off-season work has little practical appeal, and before any marked progress can be made the off-season oversupply must be eliminated. If we are to continue supplying employment the year around there are but two ways of solving this problem. The first is harvesting machinery; the second is to lengthen the harvesting season.

The first method looks rather promising at present for certain types of plantations at least. Rapid strides are being made with harvesting machinery on the mainland and in Australia and it is hoped that something along this line may be undertaken in the Islands before long.

The second method of approach, that is, extending the harvesting season through intermittent harvesting or slower harvesting has had considerable study in the Islands and has had several practical and successful demonstrations. A graph shown on page 16 of Mr. Chalmer's paper entitled "Short Cropping with Relation to Yields," presented at the annual meeting of the H. S. P. A. in 1930, brings out the possibilities of this method most forcibly. While the graph is taken from a hypothetical case that would not necessarily conform to actual experience, it shows a reduction of 35 per cent in man-days required on a plantation by eliminating the peak requirements due to continuous and forced harvesting. This is not a popular subject in the Islands as it upsets the standard Hawaiian cropping practice and beliefs; furthermore it does not offer the same possibilities in all cases. It should be borne in mind, however, at least as a possible resort in case of stringent labor shortage.

In this paper we are not dealing with the economic aspects of such a procedure other than its relation to labor and total labor performance. We believe, however, that the economic phase of this situation should receive careful and unbiased study. In spite of all the quality ratio curves showing reduced sugar returns after June and July, the writer is of the opinion that other factors than time of year have a marked if not a predominating influence in forming these curves. We feel, however, that the subject is too intricate for detailed consideration at this time. We bring it up with the hope that more study and thought may be given the matter in the future.

Relation Between Agricultural Labor and Total Labor

If man-day performance for planting, cultivating, irrigating, and other field operations can be increased by several hundred per cent the effect on total labor should be quite appreciable and should make a distinct impression on total pay roll.

Agricultural field labor averages about 35 per cent of total labor. If this is cut in two, it should affect total labor directly by about 17½ per cent. If it is cut in three it will affect total labor directly by 23 per cent. However, indirectly, it also affects other sundry labor, so that the total reduction would be somewhat more than the 17½ or 23 per cent indicated. It would also reduce material cost, for housing, medical expense, H. S. P. A. labor costs, etc., to an appreciable extent.

In order to check on the actual effect of the faster methods on total man-days and pay roll, we have made a study of this on some plantations that have adopted these methods to a greater or lesser extent. From this it would appear that the figures reported above are not far fetched or beyond practical accomplishment at the present time.

Ewa Plantation Company adopted border irrigation and layout some two years ago and today has 1,500 acres under this system. Since adopting this method on a commercial scale some two years ago the total men on their pay roll has been reduced by some 300-odd men, of which Mr. Renton considers 98 are due directly to the border irrigation.

Wailuku Sugar Company early this year adopted the Wailuku controlled cut-line system on an extended scale for their ratoons and went into straight-line layout for their plant cane. Although the changed method applied to but one-third

of their 1932 crop and to practically all their 1933 cane, and had been in operation but a few months, the effect on labor in the field and on total pay roll soon became evident. The following table gives a comparison of the man-days used in cultivation contracts for the months of April, May, June and July in 1929, 1930 and 1931. It indicates a reduction of 36 per cent in cultivation contractors over 1930 with practically the same area under contract:

CULTIVATION CONTRACTS

DAYS

	1929	1930	1931
April	5,074	5,254	3,523
May	6,557	6,750	4,454
June	5,982	6,664	4,120
July	5,649	6,688	3,946
Total	23,262	25,356	16,043

A comparison of pay roll and men on pay roll also indicates a similar reduction.

Kilauea Sugar Plantation Company has used straight-line irrigation and straight-line culture since 1922. It is the most outstanding example of increased labor performance that we have on record. In 1922, straight-line irrigation was started in the plant fields and controlled cut-line irrigation was started in the ratoons. Since then the entire place has been put under straight-line culture, machines have been used for planting whenever feasible and riding implements or tractors have replaced walking implements and hoes whenever possible.

Previous to the straight-line layout around 40 man-days per acre were required to bring cane to maturity. By 1929, this had been reduced to an average of 15 for the entire crop including planting. This indicates an improvement of nearly 300 per cent in labor performance for field work. The following table covering five-year periods is presented to show the correlation between this decrease in field labor and total labor:

KILAUEA SUGAR PLANTATION COMPANY

LABOR DATA

	1919	1924	1929
Unskilled adult males (average)	627	364	435
Planters (full time)	90	None	None
Total adult male	717	364	435
Tons cane harvested	49,362	48,310	91,899

These figures show a reduction in total labor of 50 per cent between 1919 and 1924, with approximately the same cane tonnage harvested. Between 1919 and 1929, with the cane tonnage doubled, the labor is still reduced by 40 per cent.

If we assume .6 man-day for harvesting and manufacturing (which is a fair average for Kilauea) the additional cane in 1929 over 1919 would require 25,522

additional man-days for harvesting and manufacturing or 92 additional men on pay roll working an average of 275 days per year. Deducting this from the 1929 total brings this to 343, a reduction of 52 per cent or an increased labor performance of more than 100 per cent for the whole enterprise. In this case an improvement of 300 per cent in agricultural labor performance was accompanied by a 100 per cent increase in total labor performance.

A Preliminary Investigation on the Effect of Temperature on Root Absorption of the Sugar Cane

By H. F. Duncan and D. A. Cooke

The rate of water absorbed by the roots of sugar cane on different soils and under various climatic conditions has long been a subject of debate. Is it only a matter of the per cent of moisture, or do climatic factors, such as the temperature of the soil, also have an effect? This experiment was planned with the purpose of at least finding out whether the root absorption of a sugar cane plant growing in water would be affected by the temperature of that water.

Historical

As long ago as 1860, Sachs(1), the German physiologist, first began to study the slowing down of root absorption due to lowered temperature. He noticed that many plants with large, succulent leaves, such as the tobacco and the pumpkin, wilted when cold weather set in. He decided that this was due to lessened water supply from the roots and tried an experiment to test the theory. He placed a potted tobacco plant in a warm room and after watering the soil thoroughly he surrounded the pot with ice. The plant soon began to wilt. On removing the ice and heating the soil the plant recovered without additional water.

Other investigators, the Frenchman, Vesque(2) in 1878, and the Bulgarian, Kozarov(3) in 1897 worked more accurately with potometers. This apparatus is also used in the present experiment and is described more in detail later. Both Vesque and Kozarov found slower rates of absorption at lower temperatures.

With regard to the present status of the question two modern authorities may be quoted. The American ecologist, J. E. Weaver(4), in a book published in 1926 says "The rate of root absorption, as with all the physical and chemical processes taking place within the roots, is decreased by a lowering of the soil temperature. A low temperature permits only a slow rate of water absorption."

Maximov(5) the Russian physiologist is the other writer. He states (1929) that "One of the environmental factors which most strongly influences the water supply of the plant is undoubtedly the temperature of the soil. As the general regulator of chemical reactions as well as of vital functions, temperature must naturally exert an influence on the rate of penetration of water into the cell, and consequently on the rate of absorption of water by the root." He adds, however, that all plants are not equally affected by the temperature of the soil. Certain hardy winter cereals continue to give off water when the pots in which they are growing are placed in snow. Tropical plants, on the other hand, are much more sensitive.

As far as root absorption in sugar cane is concerned, nothing can be found in the literature on this subject. J. P. Martin in an unpublished test observed previously watered sugar cane seedlings to wilt when the soil temperature was reduced to about 8° C. (46.4° F.). It is possible that other work has been done, but so far no account of it has appeared.

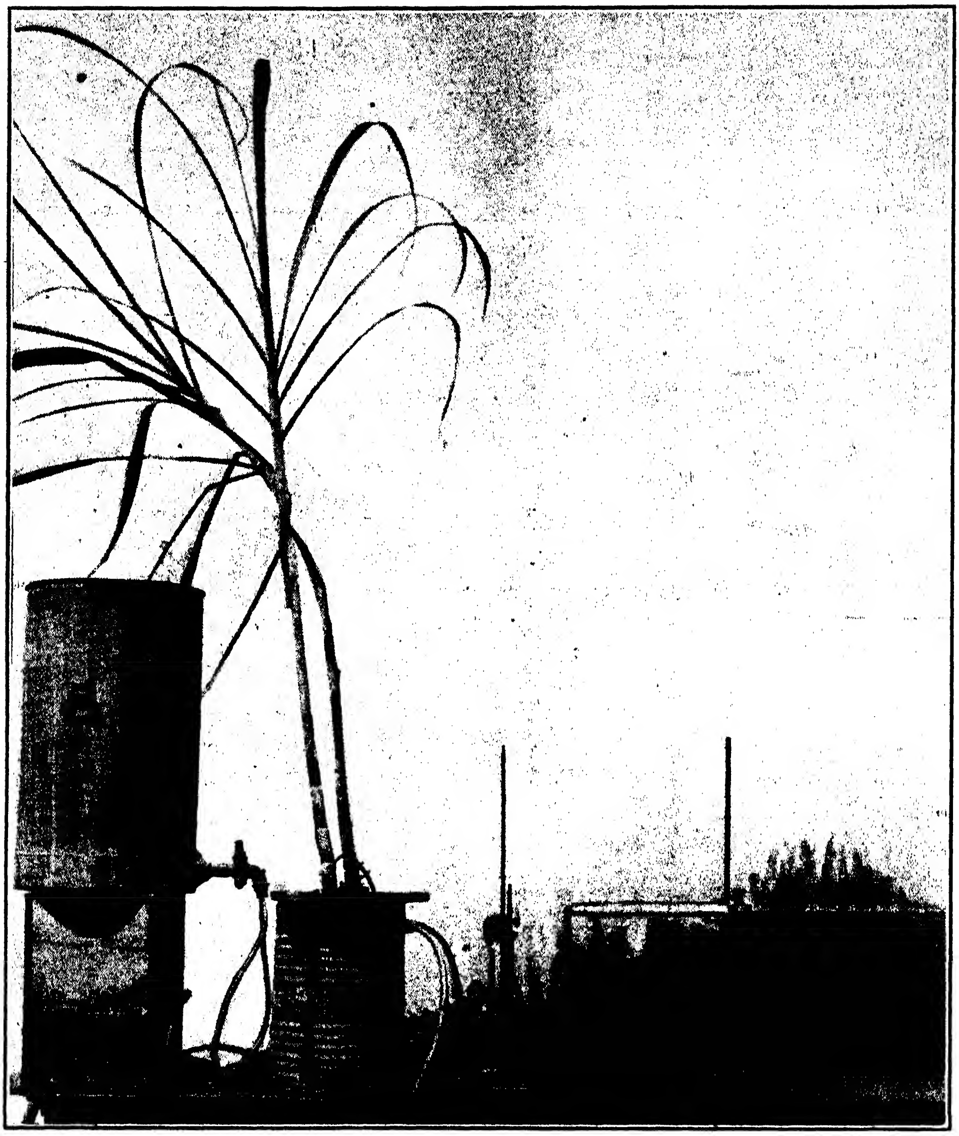

Fig. 1
The apparatus set up for an experiment.

Apparatus and Experimental Technique

The apparatus used in these experiments is known as a closed potometer (Fig. 1). This consists of a plant with its roots in an air-tight vessel containing water. As the roots absorb water, the amount is measured in some convenient manner. In these experiments the method of having a horizontal glass tube placed against a centimeter scale is employed. Water used by the plant is replaced by water from the tube and the relative amount for any given time can be read off in centimeters on the scale.

The plants to be used were selected in the field and layered, according to the method of Dr. H. L. Lyon and H. Brodie(6). This method is a modification of

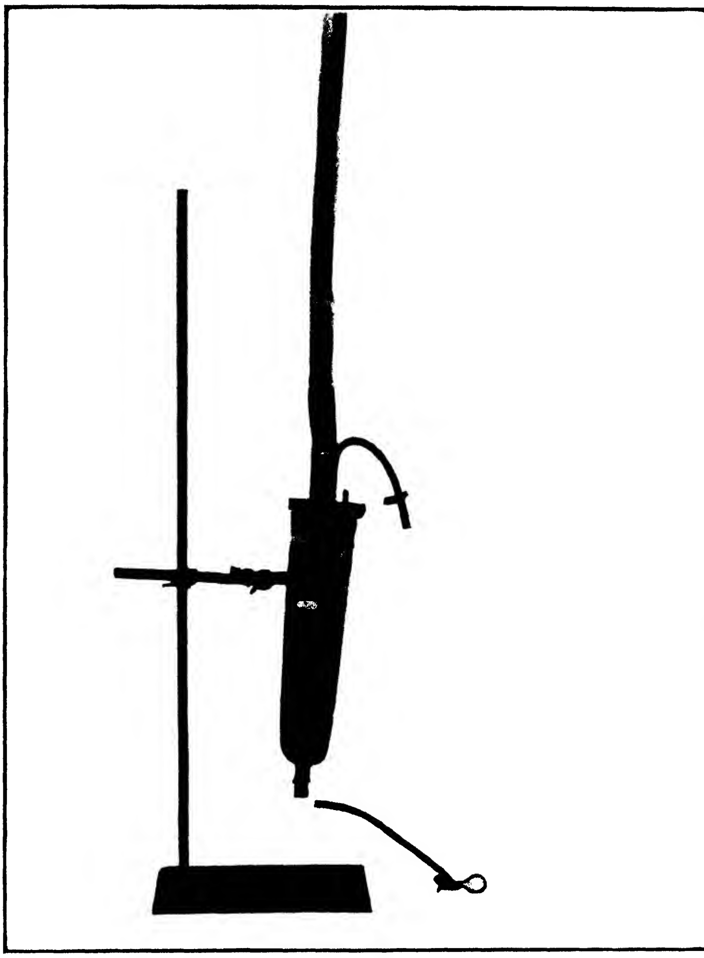

Fig. 2
A cane plant sealed in the soil percolating jar. The rubber tube at the top is used to run off the water when no experiment is in progress. The tubing at the bottom leads to the scale.

that used by Venkatraman and Thomas in India(7). H 109 was the cane variety used. Stalks of from 6 to 8 internodes were selected. After roots had developed, the stalks were cut and sealed in soil percolating jars. These jars were used as plant containers throughout this work. They were all of approximately 1500 cc. capacity and proved most satisfactory (Fig. 2).

The seal, in addition to being air-tight, had to be strong enough to support the plant. After various methods were tried, the following was adopted as the most efficient. A large cork, one-half inch thick, was cut down to a little larger than the circumference of the percolating jar. It was then halved, and hollows made in the center of each half, so that the cork fitted snugly around the cane stalk. Two other holes were bored, one for a six-inch piece of glass tubing, the other for a thermometer. The glass tube protruded one-half inch below the cork. The thermometer was inserted well down into the jar, and as near the center as the

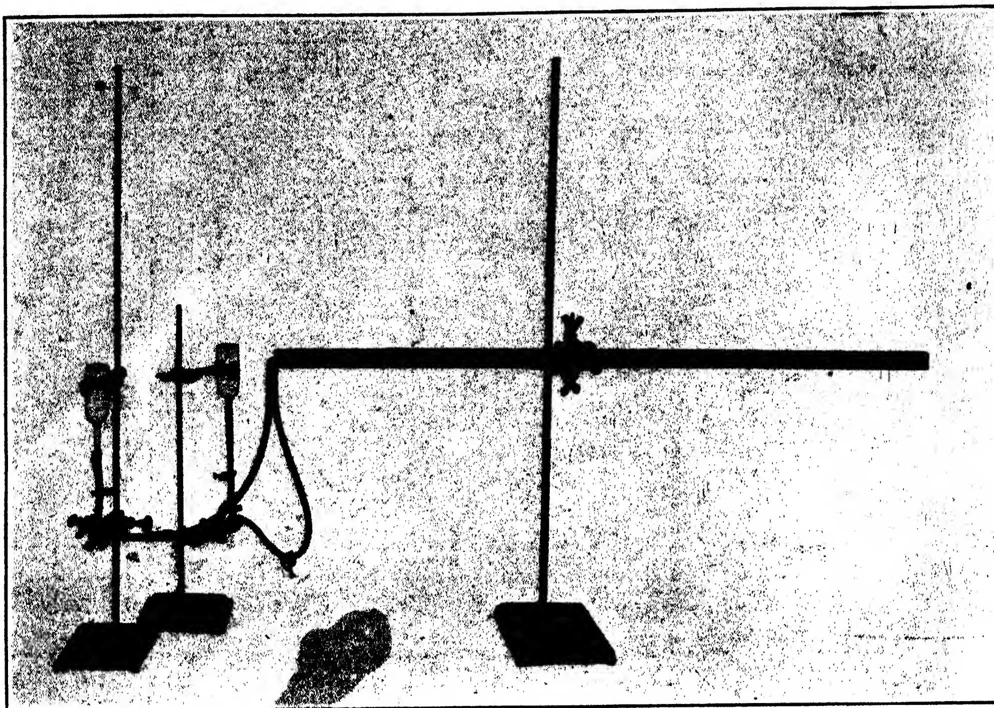

Fig. 3
The scale with the connections to the plants removed.
The funnels for filling the scale tubes to the starting point are shown at the left.

cane stalk would permit. The cork after being placed around the cane stalk, was forced into the jar,. so that its top was one-half to three-fourths of an inch below the top of the jar. Any imperfections in cutting the cork were plugged with gum and the whole surface then thickly shellaced. When dry, a one-half to one-fourth inch layer of a mixture of glycerine and litharge was laid over the cork. This was allowed to dry, and then shellaced several times.

The plant container was suspended in a water bath. The bath consisted of a calcium carbide can into which three holes were reamed. One hole was cut at the bottom for a water inlet, another at the top for an overflow, and a third on a level with the base of the plant container to allow for the passage of the rubber tubing from the percolating jar to the measuring scale.

The scale, as stated before, consisted of a horizontal capillary tube fastened to a meter stick (Fig. 3). The capillary tube was connected directly to the base of the plant container by a rubber tube, which made possible with careful handling an unbroken water column from roots to scale. A funnel was set in between the plant and scale by means of an inverted T tube. This funnel was placed high enough so that when it was full of water and the tube open, the meniscus in the scale was sent 3 or 4 centimeters past the usual starting point of the readings. On opening a screw clamp between the funnel and the main column, it was then possible to reset the meniscus when a reading was to be made.

The process of making readings was quite simple. The water levels were checked in container, funnel and scale. The aeration tube in the seal was closed

and the meniscus allowed to run as far past the starting point as the slope of the tube would allow. This never exceeded 5 cm. if the apparatus was set up correctly. The funnel clamp was then closed and as the meniscus passed the starting point on the scale, the time was taken down. After the specified time for the reading was up, the position of the meniscus was again noted, together with container and room temperatures. Any immediate environmental change such as rain, dim light, etc., was also recorded at that time. The difference between the two points gave the relative rate of root absorption in centimeters by the scale for that length of run.

Several difficulties were encountered as the experiment progressed. One was the necessity of keeping the plants in a healthy condition in spite of the air-tight seal. In the hot greenhouse, unless some aeration was provided, the water in the jars soon became foul.

This condition was finally corrected by arranging a small piece of glass tubing in the cork so that it projected about one-half inch below the bottom of the seal. A very thin air cushion was therefore formed at the top. This protected the seal and still allowed water to overflow through the tube when it was run in under a slight pressure at the bottom. When observations were not being made, a slow stream of water was in this way kept circulating through the container. When an experiment was in progress this tube was of course sealed.

First attempts at lowering the temperature of the water in the plant container were made by adding ice to the outer bath alone. This caused the plant container and tube to function as a gigantic thermometer. In cooling, the water in the container contracted, causing an abnormally large absorption reading to be made. That this increase was due to water contraction was proven by experiments in which the jar without any plant was sealed and filled with water. At constant temperature there was no flow in the scale tube. A drop in temperature, however, resulted in a flow that increased the greater the drop in temperature. An attempt was made to rectify this error by determining a coefficient of contraction per degree to be subtracted from each reading. This, however, was found to be unsatisfactory and discarded.

In the method finally adopted the water was cooled a little below the desired temperature in a large tank with an outlet in the bottom. When the temperature of the water became constant, the bath and plant containers were drained of their water for a second or so and immediately refilled from this tank. Water was then allowed to run through the container for several minutes to give both stalk and roots a chance to reach constant temperature before readings were made. The capacity of the tank was sufficiently large so that water of the same temperature could also be circulated in the outer bath during readings.

This method worked very well for the most part. The only defect was that it was difficult to determine beforehand the temperature which would result within the plant container after the cold water was added. After a number of trials, however, this could be estimated within several degrees.

The length of time for each reading made quite a difference to the results when graphed. It was found that the shorter the period of the run the more fluctuations in the curve. This was probably because small errors in the observations had an

exaggerated effect. Longer readings gave a more regular curve. On the other hand, too long a period would tend to make the apparatus not sensitive enough. In general, 5-minute runs seemed to be a good compromise.

It soon became evident that through its effect on leaf transpiration, light was one of the most important factors in root absorption. On a cloudy day root absorption fluctuated very greatly, rising during a sunny spell and falling when clouds intervened. When experiments were run at night under constant electric light, most of these irregularities were eliminated. This resulted in a more uniform curve but with much less absorption due to the lessened transpiration.

As the plants developed the rate of absorption increased to the point where over 100 centimeters of water, the length of the scale, were absorbed in 5 minutes. Glass tubes of different sizes were tried and one of one-eighth inch inside diameter used in place of the capillary tube. This slowed down the rate of flow so that 5-minute readings could again be made.

When two plants were growing under the same environmental conditions, it was found that their water consumption curves ran in a more or less fixed proportion to each other. See Charts I, II and III. A factor could therefore be obtained by dividing the root absorption of the check plant by the root absorption of the plant which was to have its root temperature lowered. Multiplying this factor each time by the absorption of the check, it was possible to determine theoretically the amount of water the other plant would have used if the temperature had not been lowered. This theoretical curve is shown by a dotted line in the graphs. This comparison made it important that for each reading of the treated plant, there must be a corresponding reading of the check at approximately the same time. Observations therefore were started within one minute of each other at the very most.

Results

In order to make interpretation of results easier, a graph was made of each run. The root absorption of both plants as well as the temperature of the air and plant container were plotted on the same sheet. The relative absorption is shown by heavy lines, while the temperature of the room and plant containers is designated by light lines.

Charts I and II show the extreme differences between absorption with sunlight during the day and at night under electric light. Notice the effect of the variations in light in Chart I, also the great difference in the total rate of absorption between night and day.

Chart III, a run made about two months later, shows the two plants still running in the same relationship to each other. Note the steady rise up to noon as the sun grows brighter.

In Chart IV the temperature was lowered from 27.5° C. (81.5° F.) to 21.5° C. (70.7° F.). Despite a falling off in root absorption in the check, there appears to be some lessening in the absorption rate due to this lowered temperature.

In Chart V the temperature was reduced to about 15° C. (59° F.). Slowing down of root absorption is quite evident. At the end of the run the plant had still not regained its normal rate of water consumption.

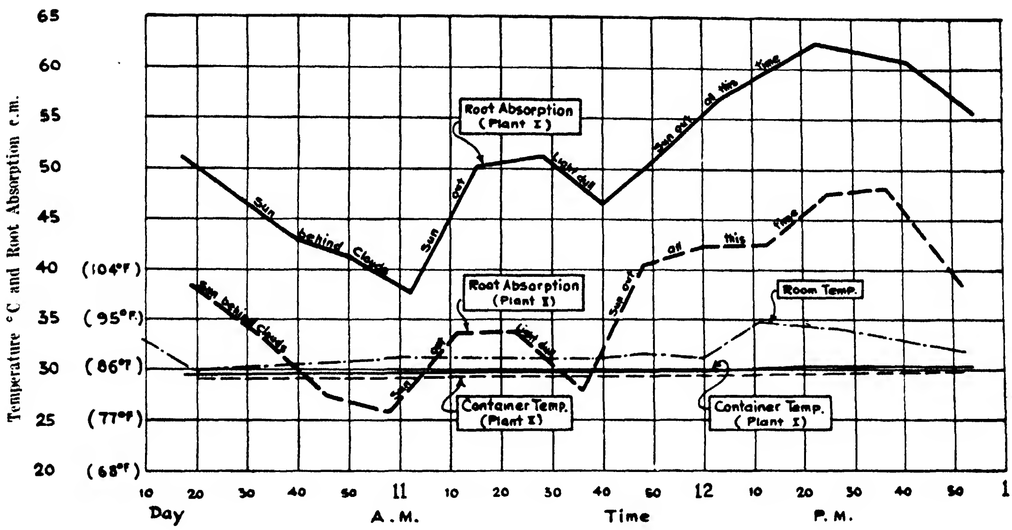

Chart I

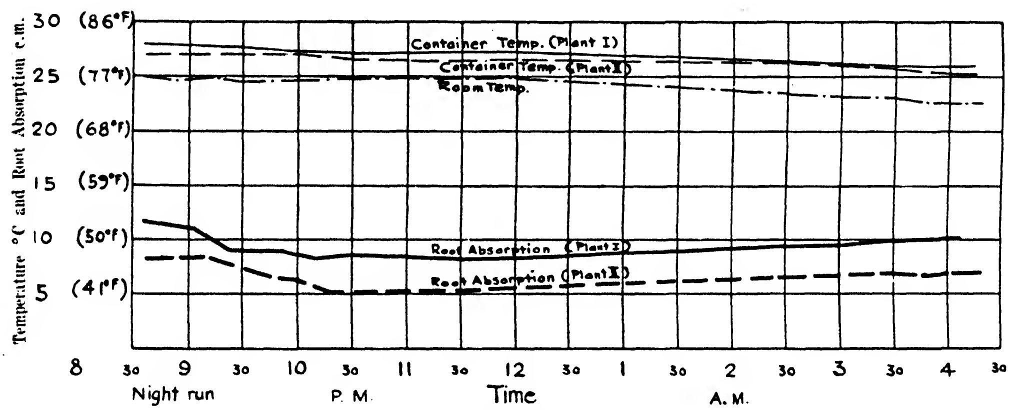

Chart II

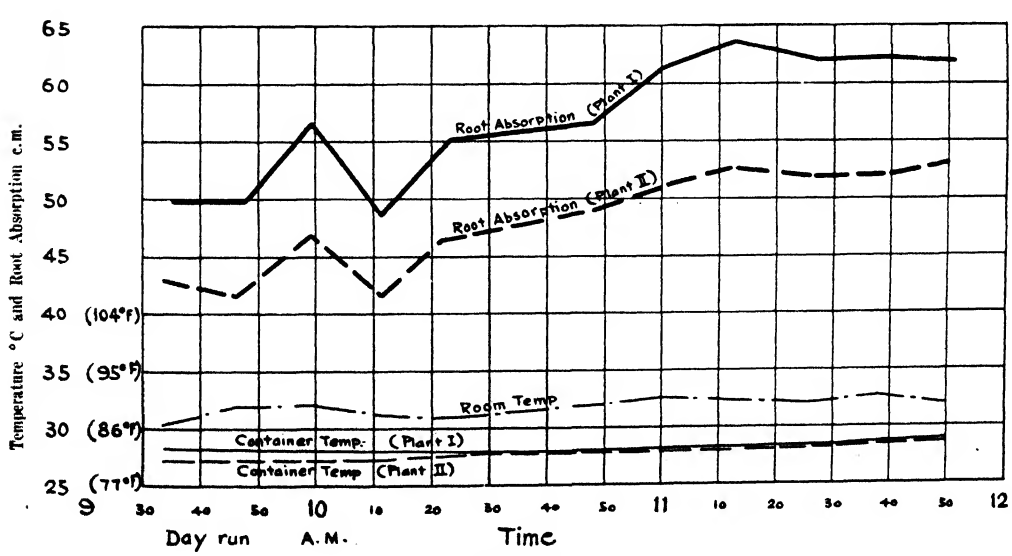

Chart III

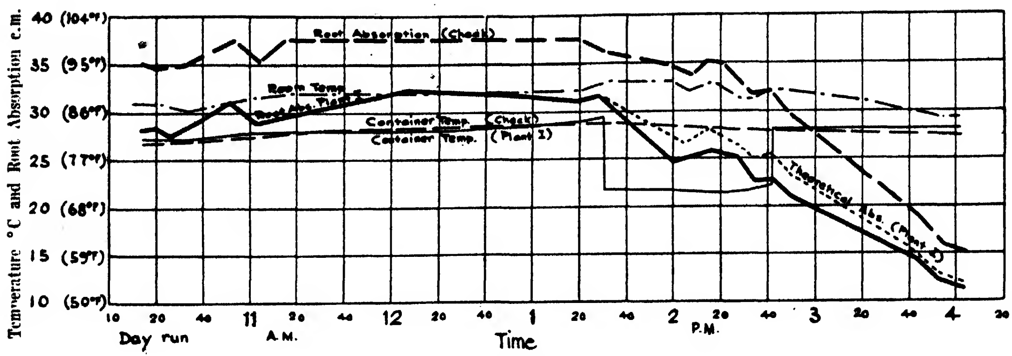

Chart IV

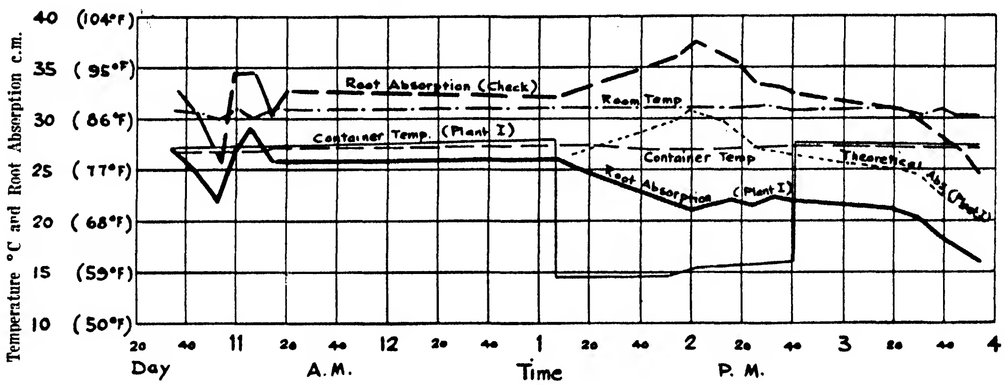

Chart V

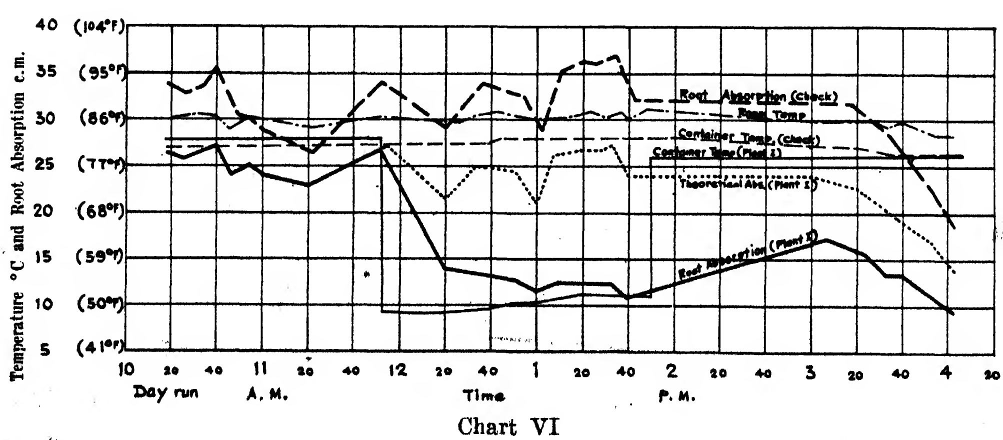

Chart VI

The temperature in Chart VI was lowered to an average of approximately 10° C. (50° F.). Here we find a correspondingly greater response due to the greater drop in temperature. It is interesting to notice that the root absorption of the check plant from 12:20 to 1:40 shows too distinct maximums which are probably due to fluctuations in the light. The plant with roots at the lowered temperature also shows the effect of the light but to a much less degree because the root temperature has evidently become the controlling factor.

It would seem that the roots were more or less permanently affected by this last fall in temperature, as root absorption was farther off from the normal after the temperature was raised than in any previous run.

Summary

1. The relative root absorption of two sugar cane plants growing in water was measured at the same root temperature and with one at normal and the other at several lowered temperatures.
2. With roots at the same temperatures the absorption curves of the two plants followed each other very closely in spite of large fluctuations. These fluctuations were probably for the most part due to the effect of light on transpiration, because they coincide with observations on the light intensity made simultaneously.
3. Light is not wholly responsible for these irregularities in the curves, however, since runs made at night under electric light still show minor ones.
4. These night runs show much less absorption, about one-fifth that of the day runs.
5. Lowering the temperature of the water surrounding the roots from 28° C. to 21° C., 15° C. and 10° C., or from 81° F. to 71° F., 59° F. and 50° F., causes progressively greater decreases in the water absorbed by the roots.
6. Roots which had been subjected to the temperature of 59° F. (Chart V) and 50° F. (Chart VI) had not recovered their former absorption rate two hours after the temperature had been raised to the original 81° F.

It is hoped that work of this sort can be continued so that a curve of root absorption at various temperatures may be worked out.

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A Further Study of the Influence of Weather on Yield

By U. K. Das

Abstract

From an analysis of the yields of the Pepeekeo Sugar Company we find:

(1) That in the last twenty years there has been a marked trend towards increasing yield of cane and sugar per acre and an equally marked but less steep trend towards decreasing quality of juice (Fig. 1).

(2) That, assuming the trends are influenced by our agriculture, the abrupt yearly fluctuations from the trend line are predominantly influenced by the conditions of temperature and rainfall.

(3) That partial regression equations developed from the trend and the weather data will give a satisfactory estimate of yields several months ahead of the grinding season.

(4) That greater use may be made of our weather data to modify our field practices, so that we shall be working with the weather conditions and not against them.

Introduction

In previous weather studies (1, 2, 3) we brought out the general relation between such weather factors as temperature, rainfall and sunshine and the yields of some of our typical plantations; but, therein, we made no attempt to study the separate effect of any of these factors or the combined effect of a number of these factors. In the present paper we propose to make such a study.

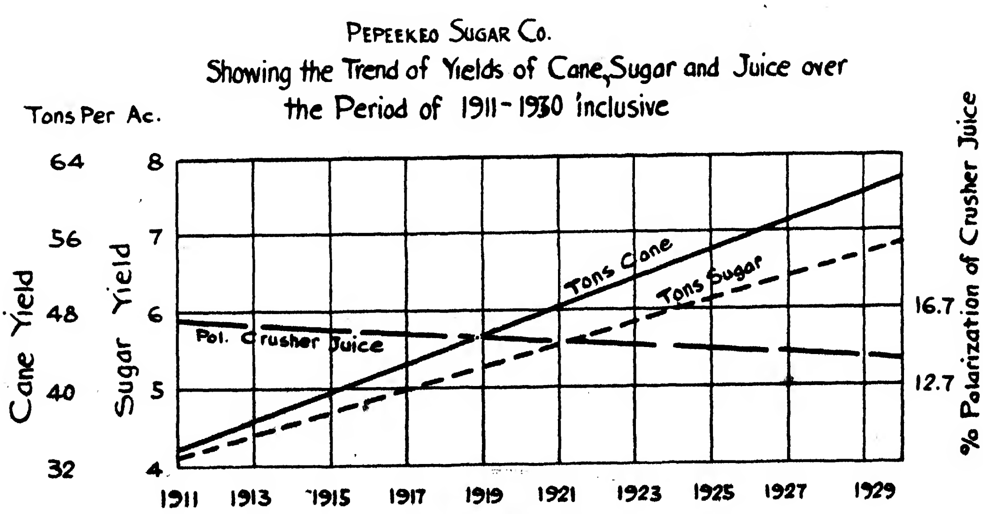


Fig. 1

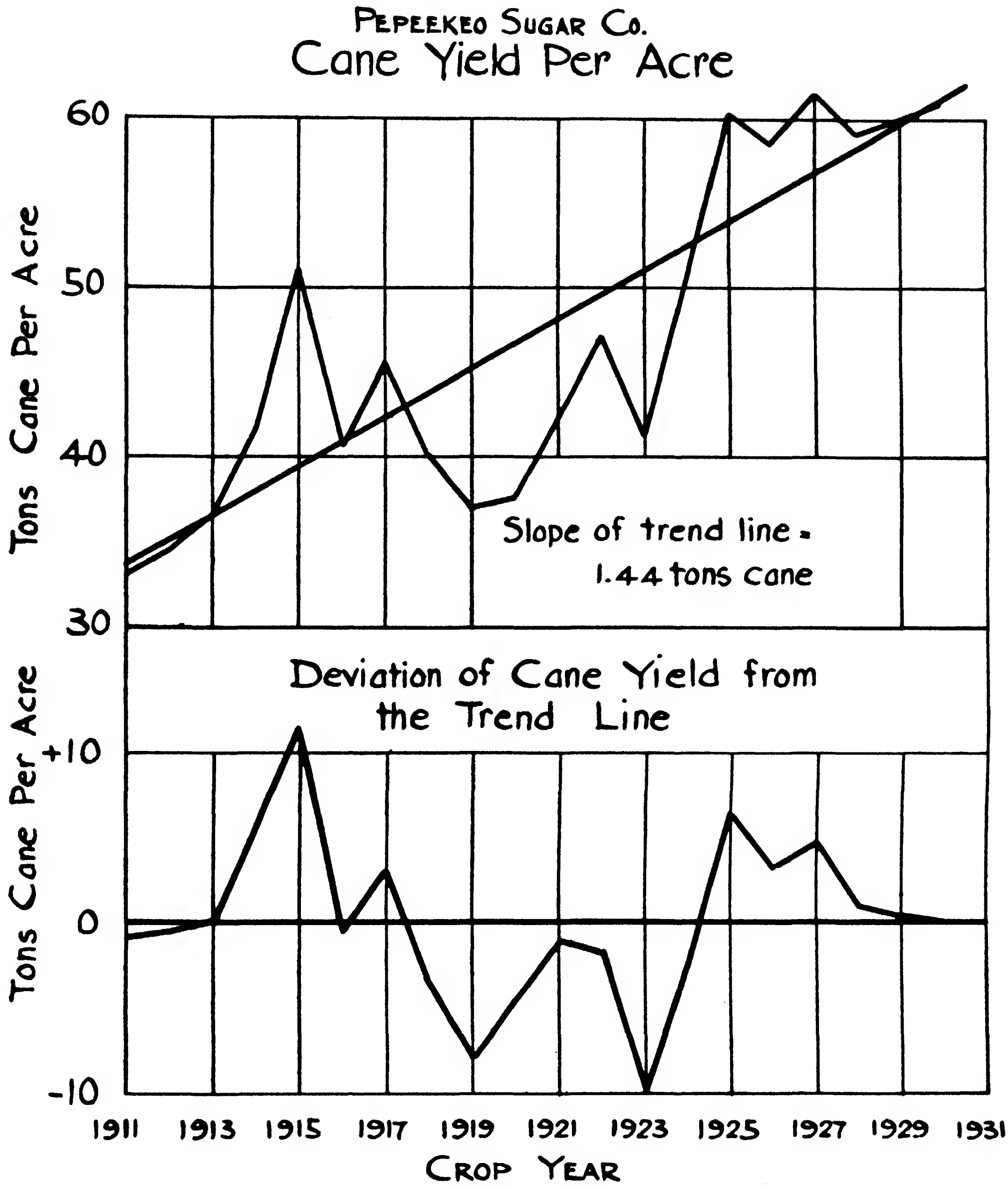


Fig. 2

SUBJECT OF STUDY—PEPEEKEO YIELDS

The yields of the Pepeekeo Sugar Company (1911-1930, inclusive) form the subject of this study. Pepeekeo would appear to be almost an ideal place for a study such as we propose, firstly because it is an unirrigated plantation depending entirely on rainfall for moisture supply, and, secondly, because at Pepeekeo the land area, the fields, the variety of cane and the length of crop have remained practically the same in the 20-year period herein studied.

The first part of this study deals with the yield of cane per acre from year to year, and the second part, the quality of crusher juice. The figures for cane yield include long crops only, but the juice figures include short ratoons as well.

Eliminating the Influence of Secular Trend

Table A and Fig. 2 show the yield of cane from 1911 to 1930. Two facts are discernible in Fig. 2. First, the trend of steadily increasing yields as years pass, and second, the abrupt fluctuations from year to year superimposed on this trend. In the past 20 years there have been marked improvements in our agricultural

TABLE A

Crop Year	Cane Yield Tons Cane	Pol % of Crusher Juice	Crop Year	Cane Yield Tons Acre	Pol % of Crusher Juice
1911	32.95	15.69	1921	47.02	14.53
1912	34.61	15.93	1922	47.92	14.19
1913	36.57	16.57	1923	41.29	14.89
1914	41.46	16.30	1924	50.12	15.22
1915	51.03	15.59	1925	60.37	14.62
1916	40.40	15.89	1926	58.69	15.00
1917	45.40	15.91	1927	61.62	13.54
1918	39.96	15.14	1928	59.19	14.17
1919	37.09	15.67	1929	60.12	14.40
1920	42.09	15.65	1930	61.17	13.79
			1931		14.26*

TABLE B

DEVIATIONS FROM THE TREND LINE OF CANE YIELD PER ACRE AND OF POLARIZATION PER CENT CRUSHER JUICE

	Slope of Trend Line =+1.44 Tons Cane			Slope of Trend Line =—.118 Per Cent Pol.		
Year	Actual Cane Yield	Trend Value	Deviation from the Trend	Actual Polarization	Trend Value	Deviation from the Thend
1911	32.95	33.76	— .81	15.69	16.27	—.58
1912	34.61	35.20	— .59	15.93	16.15	—.22
1913	36.57	36.64	— .07	16.57	16.03	+.54
1914	41.46	38.08	+ 3.38	16.30	15.92	+.38
1915	51.03	39.52	+11.51	15.59	15.80	—.21
1916	40.40	40.96	— .56	15.89	15.68	+.21
1917	45.40	42.40	+ 3.00	15.91	15.56	+.35
1918	39.96	43.84	— 3.88	15.14	15.44	—.30
1919	37.09	45.28	— 8.19	15.67	15.33	+.34
1920	42.09	46.72	— 4.63	15.65	15.21	+.44
1921	47.02	48.18	— 1.16	14.53	15.09	—.56
1922	47.92	49.62	— 1.10	14.19	14.97	—.78
1923	41.29	51.06	— 9.77	14.89	14.85	+.04
1924	50.12	52.50	— 2.38	15.22	14.74	+.48
1925	60.37	53.94	+ 6.43	14.62	14.62	000
1926	58.69	55.38	+ 3.31	15.00	14.50	+.50
1927	61.62	56.82	+ 4.80	13.54	14.38	—.84
1928	59.19	58.26	+ .93	14.17	14.23	—.09
1929	60.21	59.70	+ .51	14.40	14.15	+.25
1930	61.17	61.14	+ .03	13.79	14.03	—.24
1931				14.26	13.91	+.35

practices, and, therefore, it would seem reasonable to assume that the trend reflects our agricultural progress, while the fluctuations from year to year, the progress

* Crop not finished.
Pol figures include data up to August 22, 1931 only.

of weather.* For this reason we need to eliminate the influences of secular trend, before we proceed to analyze the influences of weather.

Fig. 2 shows that the correlation between time (i. e., years elapsed since 1911) and the yield is positive and linear. We may, therefore, treat time as a variable and determine the coefficient of regression of time on cane yield or, in other words, determine the average increase in yield corresponding to the passage of a year's time. (Appendix A.)

The trend line thus determined (Fig. 2) shows that beginning at 33.76 tons of cane per acre in 1911, the yield increases on the average by 1.44 tons of cane a year.

The departures of the actual yields from this trend line may now reasonably be attributed to weather influences. These departures are shown in Table B and Fig. 2.

Obtaining the Coefficients of Correlation

We next proceed to obtain the coefficients of correlation between the departures of cane yield and the departures of rainfall or temperature. As the crops under consideration were all about 23 to 24 months old, the coefficients are obtained for all the months during which a crop has been in the field. For this purpose we assume that an average crop, say 1930, starts in July of 1928, and is harvested 23 to 24 months later, i. e., in April or May of 1930. We also assume that an average yield is obtained under conditions of average weather and that under the conditions of Pepeekeo the relation between temperature, rainfall and cane growth is linear.

TABLE C

COEFFICIENTS OF TOTAL CORRELATION BETWEEN CANE YIELD AND VARIOUS WEATHER FACTORS

	Mean Maximum Temperature and Yield	Mean Minimum Temperature and Yield	Rainfall and Yield
1st Season:			
July	+.36	+.18	....
August	+.37	+.56	+.03
September	+.68	+.37	+.10
October	+.64	+.50	+.06
November	+.45	+.30	—.01
December	+.40	+.51	—.04
2nd Season:			
January	+.47	—.05	—.32
February	+.45	+.09	—.55
March	+.55	+.04	—.63
April	+.49	+.12	—.43
May	+.39	+.22	+.45
June	+.23	+.41	+.28
July	+.22	+.48	+.09
August	+.18	+.45	+.67
September	+.21	+.45	+.34

* The trend line may also be influenced to a certain extent by a trend in weather conditions. Preliminary examination of the data, however, fails to show any marked trend in weather.

TABLE C—Continued

	Mean Maximum Temperature and Yield	Mean Minimum Temperature and Yield	Rainfall and Yield
October	+.35	+.02	+.06
November	+.52	+.26	—.06
December	+.43	+.26	+.03
Harvesting Season:			
January	+.48	+.13	—.38
February	+.27	—.08	—.26
March	+.50	+.15	—.33
April	+.49	—.03	—.03
2nd Season:			
January to March (combined)			—.63

Meaning of the Correlation Coefficient

The correlation coefficient is a mathematical symbol which shows at a glance the nature and the extent of the relation between two quantities. The coefficient can be anything from —1 to +1. Both the sign and the magnitude of the coefficient are of significance. A plus sign means a positive correlation between the quantities, i. e., an increase or decrease in one is associated with an increase or decrease in the other. A minus sign shows a negative correlation, i. e., an increase in one is associated not with an increase but with a decrease in the other and vice versa. The coefficient is zero when there is no relation whatsoever between the two quantities and —1 or +1 when there is perfect agreement between the two.

Rarely ever in practice does one find a perfect correlation, but it is generally agreed that where the number of pairs correlated is 20 (20 years of crop and weather data in our case) then a coefficient of .50 or over may be accepted as showing a marked relation between the correlated items.

In weather and crop studies, the periods showing such marked relation are often termed "critical periods," implying thereby that the crop is likely to be permanently affected by the conditions of weather prevailing during these critical periods. For a better understanding of our crop, we need, therefore, to know the duration as well as the importance of these critical periods.

Discussion of Results

The coefficients of correlation are presented in Table C and Fig. 3.

Temperature: We have considered two measures of temperature, namely, mean monthly maximum and mean monthly minimum temperature. We believe that a study of these two measures separately will give us a better understanding of the growth processes of cane than a study of mean temperature alone.

Fig. 3 shows that as regards maximum temperature, all the months show positive correlation to cane yield; in other words, high maximum temperature always tends to increase the cane yield. The same is more or less true of minimum temperature. We may, therefore, conclude that at Pepeekeo temperature is definitely a limiting factor.

In Fig. 3, we also note that while all the months show positive relation between maximum temperature and cane yield there are only three months which appear

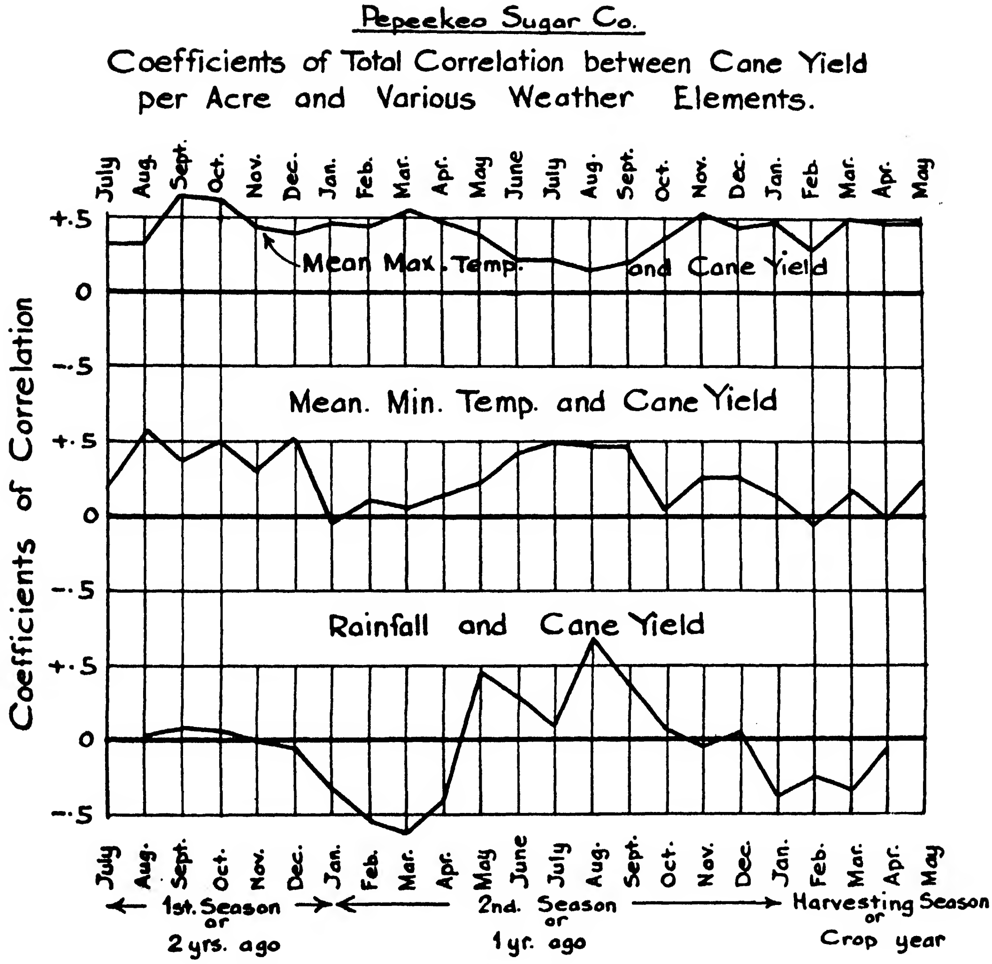


Fig. 3

to have "critical" significance. These are the fall months of September, October of the first season, and the month of March of the first winter of crop growth. This is in perfect agreement with the conclusions arrived at in our preliminary study of the sugar yields of this plantation.

These critical periods lend support to the increasing realization that the first several months in the life of a crop are of the greatest moment, because it is in the first few months that the stand is being established, and it is in this period that the cane is growing by nature at a rapid rate. Conditions of temperature at this period of formation and rapid growth affect the crop to a greater degree than at any subsequent period.

The high positive coefficient of correlation for March of the first winter probably reflects the injurious effect of Pepeekeo winters, which are generally wet and cold.

Rainfall: Fig. 3 shows that high yields are correlated with low rainfall in the first winter and high rainfall in the second season summer, and low rainfall again in the grinding season. The importance of the two latter periods are generally recognized, but not so the extremely injurious effects of excessive rain in the first winter. The harmful effects of wet first winter may be as follows: First, high

rainfall lowers the temperature; second, probably it saturates the soil, driving out all air, and giving rise to a very unhealthy physical condition; third, coming about the time when second season application of nitrogen is being made, high rainfall probably causes a great loss of nitrates from the soil.

The critical periods appear to be the entire period of January to March of the first winter and the month of August of the second season summer.

In drawing repeated attention to these critical periods, we do not imply that the conditions in the other months are of no consequence, but we simply suggest that under normal conditions of weather, the other periods pretty well take care of themselves so long as the critical periods are as desired.

The Combined Effect of Weather—Multiple Correlation

The coefficients of correlation obtained thus far show that cane yield at Pepeekéo is markedly influenced by temperature in the fall months of the first season and rainfall in the first winter and also in the month of August of the second season summer. These coefficients do not, however, tell us of the relative importance of these periods, neither do they show as to what proportion of the total variation from year to year can reasonably be accounted for by the weather conditions in these critical periods. What we need, therefore, to know is the partial correlation between temperature or rainfall and yield (i. e., the independent correlation of any of these factors with yield when the other factors are kept constant) and, then, the multiple correlation, or, in other words, the combined effects of all of these factors on yield.

Following the methods developed by Yule (4) we have worked out the partial and the multiple coefficients and also the regression equation showing the relation between yield, temperature and rainfall.

The coefficient of multiple correlation, after adjusting for the paucity of our data, is 0.89. The square of the multiple coefficient, otherwise known as the coefficient of determination (R^2), is said to measure the percentage of total variation accounted for by the factors combined. In the present case, $R^2=0.79$, that is, about 79 per cent of the total variation in the yield of cane from year to year at Pepeekeo can reasonably be attributed to the influence of rainfall and temperature (or others associated with these two factors). The coefficient of determination would probably be greater if other aspects of weather were taken into consideration.

Weather conditions thus appear to be the biggest factor in causing the tremendous yearly fluctuations in yield.

The regression equation is as follows:

$$D=0.781t-0.107r_w+0.437r_s$$

Where D=departure of cane yield (in tons per acre) from the trend line.

t=deviation from the average of mean maximum temperature (F°) in October, first season.

r_w=deviation from average of inches rainfall in January, February and March of the first winter.

r_s=deviation from average of inches rainfall in August of second season summer.

TABLE D

ACTUAL YIELD OF CANE AND THE YIELD CALCULATED BY THE PARTIAL REGRESSION EQUATION

Crop Year	A Departures Calculated from the Equation	B Actual Departures from the Trend Line	C Trend Line Values	D Calculated Yield of Cane (A + C)	E Actual Yield of Cane	Difference Between Actual and Estimated Yields (E — D)
1911	— .69	— .81	33.76	33.07	32.95	— .12
1912	— 1.43	— .59	35.20	33.77	34.61	+ .84
1913	+ .27	— .07	36.64	36.91	36.57	— .34
1914	— 1.91	+ 3.38	38.08	36.17	41.46	+5.29
1915	+11.32	+11.51	39.52	50.84	51.03	+ .19
1916	+ .37	— .56	40.96	41.33	40.40	— .93
1917	+ 2.75	+ 3.00	42.40	45.15	45.40	+ .25
1918	— 1.91	— 3.88	43.84	41.93	39.96	—1.97
1919	— 6.95	— 8.19	45.28	38.33	37.09	—1.24
1920	— .42	— 4.63	46.72	46.30	42.09	—8.65
1921	— 4.81	— 1.16	48.18	43.37	47.02	—1.28
1922	— 4.37	— 1.70	49.62	45.25	47.92	+1.77
1923	— 7.70	— 9.77	51.06	43.36	41.29	—2.07
1924	— 2.53	— 2.38	52.50	49.97	50.12	+ .15
1925	+ 3.31	+ 6.43	53.94	57.25	60.37	+3.12
1926	+ 1.10	+ 3.31	55.38	56.48	58.69	+2.21
1927	+ 5.83	+ 4.80	56.82	61.65	61.62	— .03
1928	+ .39	+ .93	58.26	58.65	59.19	+ .54
1929	+ .91	+ .51	59.70	60.61	60.21	— .40
1930	— .63	+ .03	61.14	60.51	61.17	+ .66
1931*	+ 5.83					
1932*	+ 4.33					

The actual departures of yield and the departures calculated by our equation are shown in Table D and Fig. 4. The agreement of the two sets of figures is very striking.

The error of estimate calculated from the coefficient of multiple correlation is 2.5 tons of cane. In other words, if we were to form an estimate of cane yield departures from the temperature and rainfall data of the three critical periods and if other factors in production remained the same, then our estimate would come within 2.5 tons of the actual yield in about 67 per cent of cases, or within 5 tons of the actual in 95 out of 100 cases. Surely no empirical manner of estimating would yield results that would agree so well with the actual.

This regression equation can easily be transformed so as to give yields in actual tons per acre rather than as departures from the trend line. What we need to do is simply to add the equation for the trend line. The transformed equation is as follows:

* These two crops were not included in the original study. These figures are, therefore, in the nature of a prediction of yields from weather data.

Cane Yield $=33.76+1.44Y+0.781t-0.107r_w+0.437r_s$ in tons per acre

Where $Y=$ number of years elapsed since 1911, the other symbols have the same meaning as in the first equation.

The actual yield of cane per acre and the yield calculated from the new equation are also given in Table D and Fig. 4. The degree of agreement between the actual and the calculated yields is even closer in this Fig. 4.

The coefficient of correlation between years elapsed since 1911 and yield of cane is 0.86. The coefficient of determination is .74. If 74 per cent of the total variation between 1911 and 1930 is accounted for by the progressive trend, we are left with about 26 per cent to be accounted for by weather. We have seen that temperature and rainfall account for about 80 per cent of the variations left over

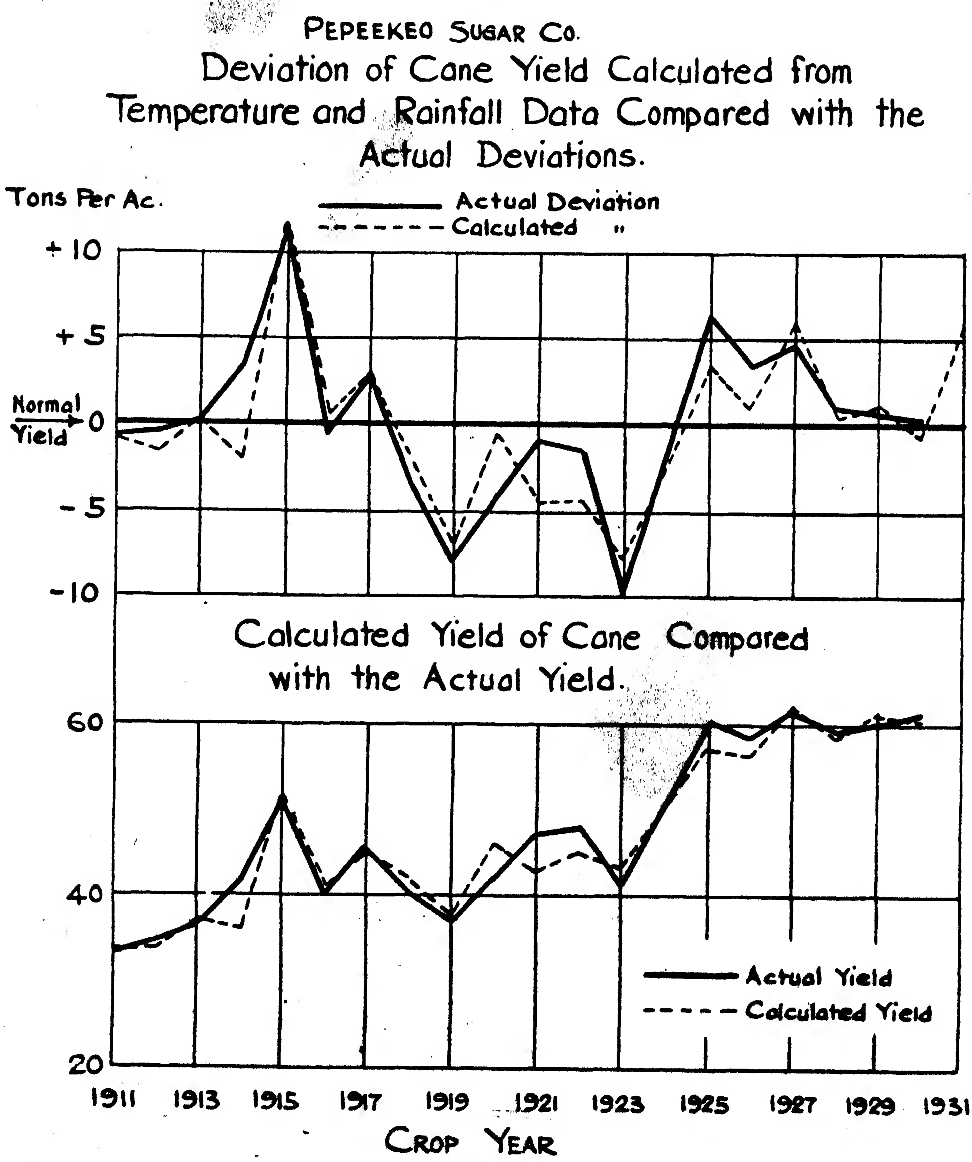


Fig. 4

after eliminating the trend line. Temperature and rainfall, therefore, account for 80 × 26 or fully 20 per cent of the total variation. Trend line and weather conditions together account for nearly 94 per cent of the total variations in yield at Pepeekeo for 1911 to 1930, leaving only 6 per cent to be accounted for by other causes.

Relative Importance of Temperature and Rainfall

The regression equations show that every degree of temperature above the average in October of the first season increases the yield by 0.781 ton of cane, while one inch of rainfall in August increases yields by only 0.437 ton. One degree of temperature above average would, therefore, be worth 179 per cent as much as one inch of rainfall above average. While this is true, the Pepeekeo records show that temperature deviations never exceeded 5 degrees while rainfall deviation in August was as high as 19 inches. The rainfall variations are, therefore, of greater practical interest at Pepeekeo than the variations of temperature.

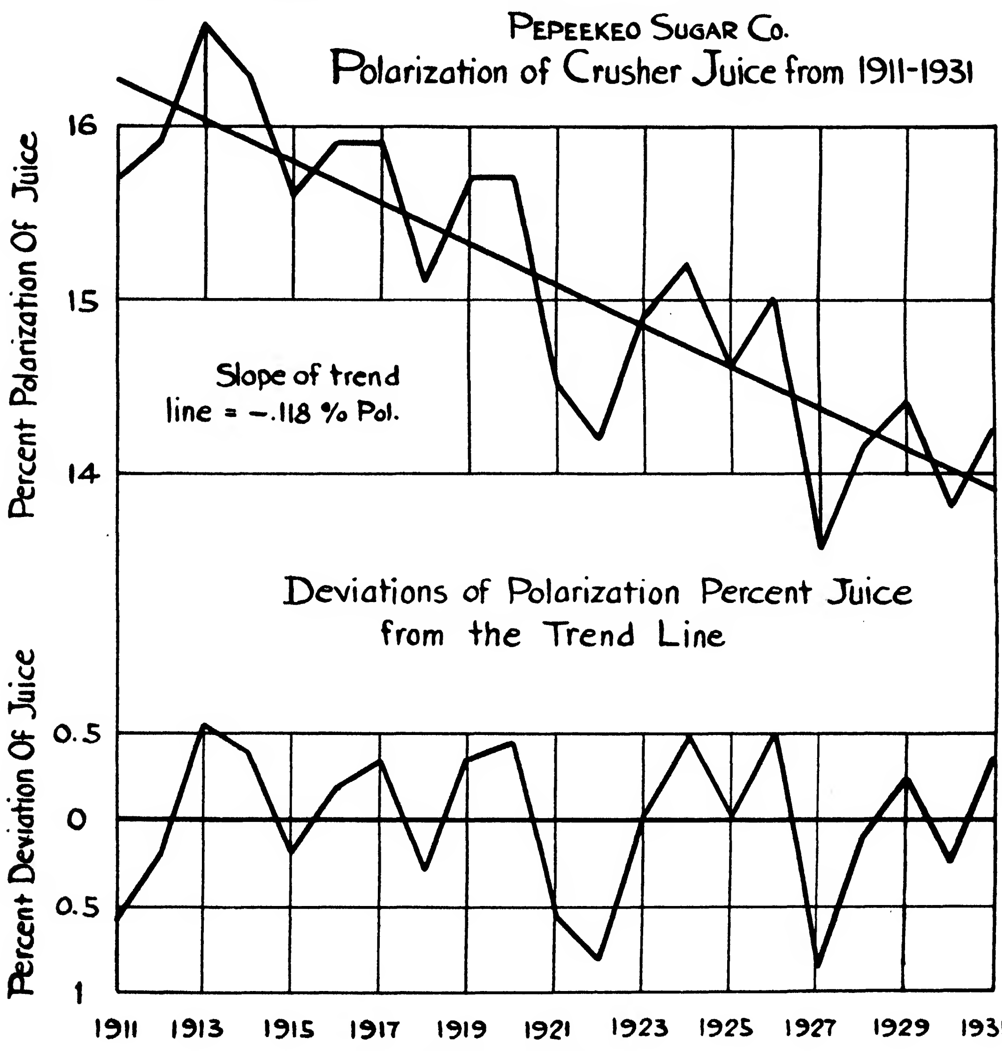


Fig. 5

The loss in cane yield due to an additional inch of rain in the first winter is only 0.107 ton. Therefore high rainfall in the month of August is of greater importance than low rainfall in the first winter.

Juice Quality

Table A and Fig. 5 show the polarization per cent crusher juice from 1911 to 1930. We see in Fig. 5 that whereas in cane yield there was a marked upward trend, in the quality of juice there is an equally marked trend downwards. In this case also, the trend appears to be a straight line. We have accordingly calculated the regression of time on yield as we did in the case of cane yield. The equation of trend line is: Per cent Pol of Juice=16.27—0.118Y.

Where Y=number of years elapsed since 1911.

The departures from this trend are then correlated with temperature and rainfall data.

TABLE E

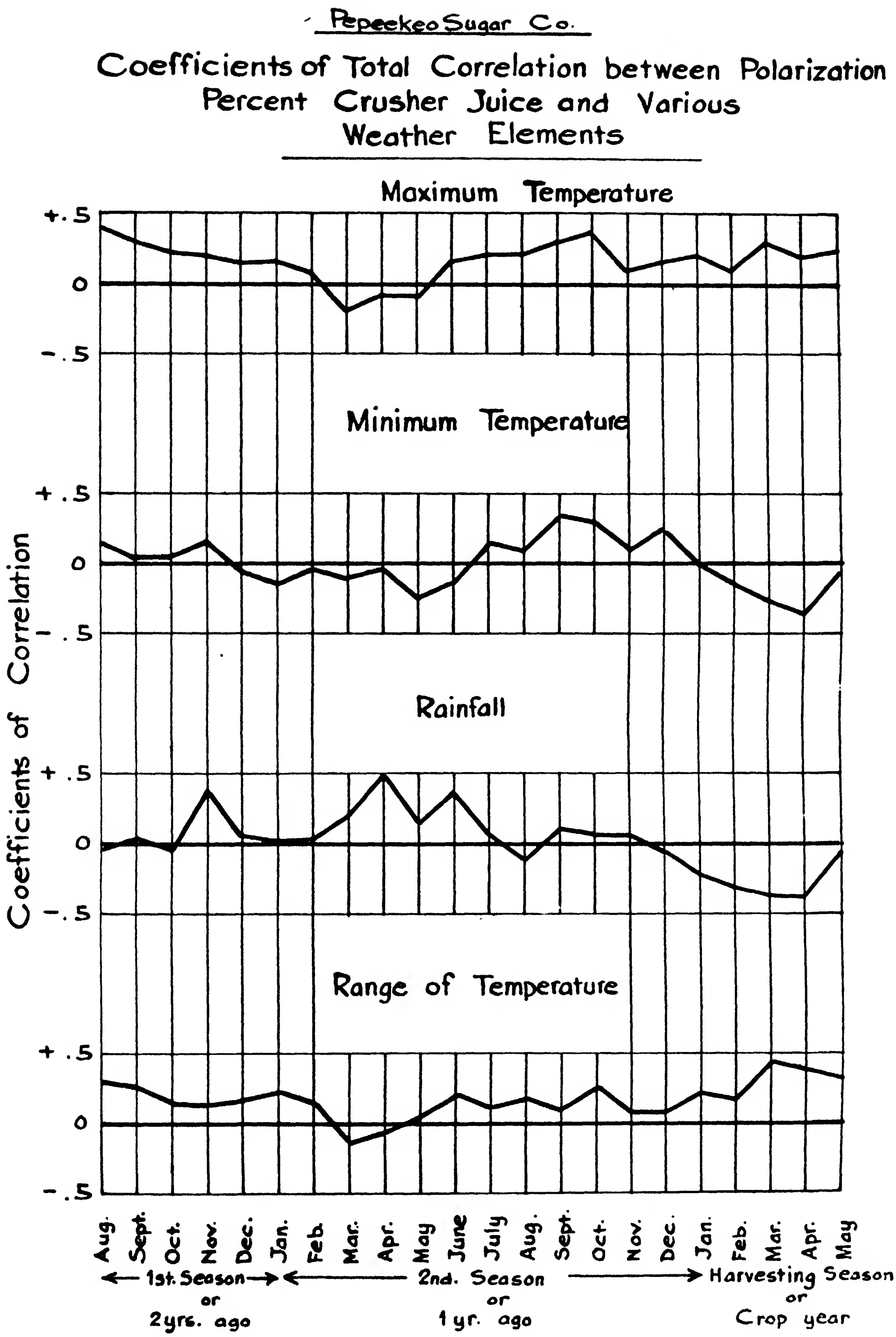
COEFFICIENTS OF CORRELATION BETWEEN POLARIZATION PER CENT CRUSHER JUICE AND VARIOUS WEATHER FACTORS

	Mean Maximum Temperature	Mean Minimum Temperature	Mean Daily Range of Temperature	Monthly Rainfall
1st Season:				
August	+.35	+.14	+.18	—.03
September	+.28	+.05	+.23	00
October	+.23	+.04	+.13	—.06
November	+.18	+.16	+.12	+.39
December	+.15	—.01	+.16	+.06
2nd Season:				
January	+.14	—.14	+.23	+.01
February	+.07	—.04	+.16	+.13
March	—.20	—.11	—.15	+.20
April	—.11	—.06	—.07	+.49
May	—.09	—.25	+.03	+.17
June	+.15	—.14	+.22	+.34
July	+.18	+.13	+.11	+.03
August	+.21	+.07	+.15	—.12
September	+.30	+.33	+.07	+.09
October	+.36	+.29	+.24	+.04
November	+.10	+.11	+.06	+.05
December	+.13	+.24	+.06	—.03
Harvesting Season:				
January	+.18	—.02	+.19	—.25
February	+.10	—.15	+.16	—.33
March	+.28	—.29	+.40	—.41
April	+.21	—.37	+.35	—.41
May	+.23	—.07	+.28	—.09

Discussion of Results

The coefficients of correlation are shown in Table E and Fig. 6.

Temperature: From the trend of the values of correlation coefficient in Fig. 6 we conclude that for good juice mean maximum temperature should generally



Pepeekeo Sugar Co.
Coefficients of Total Correlation between Polarization Percent Crusher Juice and Various Weather Elements
Maximum Temperature
Minimum Temperature
Rainfall
Range of Temperature
Coefficients of Correlation
+.5
0
-.5
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May
1st. Season or 2 yrs. ago
2nd. Season or 1 yr. ago
Harvesting Season or Crop year

Fig. 6

be above the average, except possibly in the spring months of the second season, and minimum temperature should generally be lower than the average except in the summer and fall months. During the ripening and harvesting season particularly we should have low minimum temperatures and high maximum temperatures. As high maximum temperature is believed to be an index of bright, sunny days and low minimum temperature of cool, clear nights, the coefficients indicate that good juices are likely to be obtained if the days are bright and sunny and the nights cool during the ripening season. This is in agreement with our conclusions deduced from a study of the juice quality of the Ewa Plantation Company (3).

Range of Temperature: Daily range of temperature is the difference between the daily maximum and daily minimum temperature. High range of temperature generally signifies bright days with high maximum temperature, and clear and cool nights with low minimum temperature.

The coefficients of correlation in Table E and Fig. 6 show that good juices are generally associated with high range of temperature during the entire period of crop growth.

This bears out the conclusion arrived at in our previous studies, that range of temperature has a pronounced effect on juice quality.

However, neither maximum or minimum temperature nor range of temperature show any "critically" significant relation to juice quality, from which we conclude that probably there are other factors which exercise a greater influence on the quality of juice at Pepeekeo than temperature.

Rainfall: The trend of values of these coefficients (Fig. 6) indicates an increasing demand of additional rain till the month of April in the second season, and from then on the demand tapers off in much the same way as the application of water is tapered off on the irrigated plantations. In the harvesting season high rainfall is found to be highly detrimental.

The harmful effects of excessive rainfall in the grinding season are very generally recognized, but we have heard very little as yet as to the beneficial effects of high rainfall in the winter and spring months of the second year. The trend of the coefficients is so definite that we feel that here we are face to face with a genuine weather and crop relation. The following is offered as a possible explanation of the significant relation between high rainfall in the spring months of the second season and juice of high quality.

At Pepeekeo the second season application of nitrogen is generally made in the months of March and April. We have suggested elsewhere in our studies (5) that there are good reasons to believe that the generally poor juices obtained nowadays as compared with 10 or 20 years ago are probably due in a large measure to increasing applications of soluble nitrogen, especially the application in the second season. It is our belief that fields of cane fed with large quantities of nitrogen do not generally reach full maturity at the time they are harvested.

If these considerations are justified, it would appear that any factor that tends to withdraw the nitrogen from the soil or make it more easily assimilated by the plant, that factor would thereby cause an improvement in the quality of juice.

High rainfall in the second season spring may be a factor of the same nature. It probably leaches out a substantial amount of the nitrogen from the soil, or by

encouraging cane growth causes most of the nitrogen to be taken up early in the season. If the weather at this period were dry, the nitrogen would, probably, stay in the soil to be taken up later in the season, perhaps too late in the season to yield cane of good maturity.

The actual sequence of rainfall in a group of four years in which juice quality was much above the average and in another group of four years in which the quality was much below, is shown in Fig. 7.

TABLE F

ACTUAL POLARIZATION OF CRUSHER JUICE AND THE POLARIZATION OF JUICE CALCULATED BY THE REGRESSION EQUATION

Crop Year	A Departures Calculated from the Equation	B Actual Departures from the Trend Line	C Trend Line Values	D Calculated Pol of Juice	E Actual Pol of Juice	(E — D) Difference Between the Actual and Calculated Pol
1911	—.11	—.58	16.27	16.16	15.69	—.47
1912	—.08	—.22	16.15	16.07	15.93	—.14
1913	+.32	+.54	16.03	16.35	16.57	+.22
1914	+.02	+.38	15.92	15.97	16.30	+.33
1915	—.27	—.21	15.80	15.53	15.59	+.06
1916	+.28	+.21	15.68	15.96	15.89	—.07
1917	+.01	+.35	15.56	15.57	15.91	+.34
1918	—.52	—.30	15.44	14.92	15.14	+.22
1919	+.25	+.34	15.33	15.58	15.67	+.09
1920	—.18	+.44	15.21	15.03	15.65	+.62
1921	—.30	—.56	15.09	14.79	14.53	—.26
1922	—.15	—.78	14.97	14.82	14.19	—.63
1923	—.18	+.04	14.85	14.67	14.89	+.22
1924	+.45	+.48	14.74	15.19	15.22	+.03
1925	—.05	00	14.62	14.57	14.62	+.05
1926	+.49	+.50	14.50	14.99	15.00	+.01
1927	—.33	—.84	14.38	14.05	13.54	—.51
1928	+.26	—.09	14.26	14.52	14.17	—.35
1929	—.22	+.25	14.15	13.93	14.40	+.47
1930	—.36	—.24	14.03	13.67	13.79	+.12
1931	+.58	+.35	13.91	14.49	14.26	—.23
1932						

Calculation of Juice Quality From Weather Data

As in the case of cane yields here we have calculated the coefficient of multiple correlation between the percentage of polarization of crusher juice and the various weather data.

The highest coefficient of multiple correlation obtained after trying out several combinations is 0.69. The coefficient of determination ($=R^2$) is only .47. In other words, only about half the variations in the juice quality from year to year could be attributed to weather conditions.

It is quite probable that the fluctuations in the per cent polarization of crusher juice are influenced by many other causes of which we know very little at present.*

* One source of trouble may be the inclusion of short ratoons in the juice figures of some recent years. A small area of short ratoons yielding poor juices may lower the average juice figure for the whole crop.

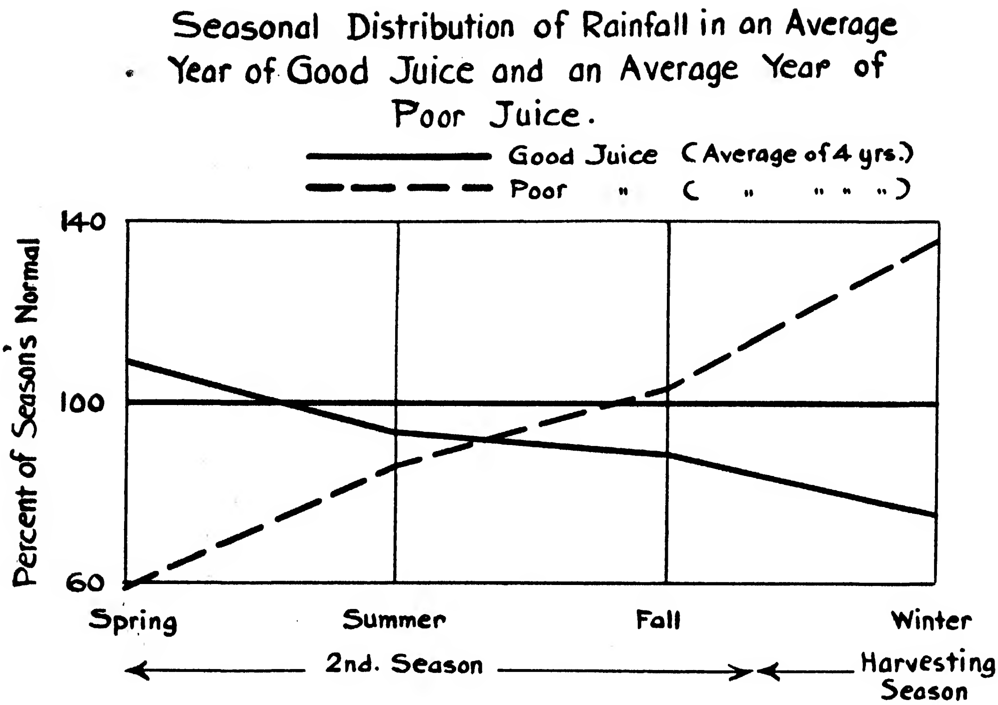


Fig. 7

The equation connecting polarization of juice with weather data is as follows:
$D=0.029r_1-0.022r_2+0.056$ r.t

Where D=deviation from the trend line of per cent polarization of crusher juice,

r_1=deviation from average of inches rainfall in April of the second season spring,

r_2=deviation from the average of inches rainfall in April of the grinding season,

r.t=deviation from average of range of temperature in March of the grinding season.

By adding the equation of the trend line to this equation, we obtain as before a new equation from which we can calculate the actual percentage of polarization. The new equation is as follows:

Per cent Pol of Crusher Juice$=16.27-0.118Y+0.029r_1-0.022r_2+0.056$ r.t; where Y is the number of years elapsed since 1911.

The new equation (trend and weather factors combined) accounts for only 86 per cent of the total variation from 1911 to 1931. The prediction value of this equation is, therefore, not nearly as good as is the equation obtained in the case of cane yield.

The calculated and the actual figures are shown in Table F and Fig. 8. We note that the greatest divergence of the actual and the calculated yield is obtained for the crop of 1920. In checking up the month to month progress of rainfall, we

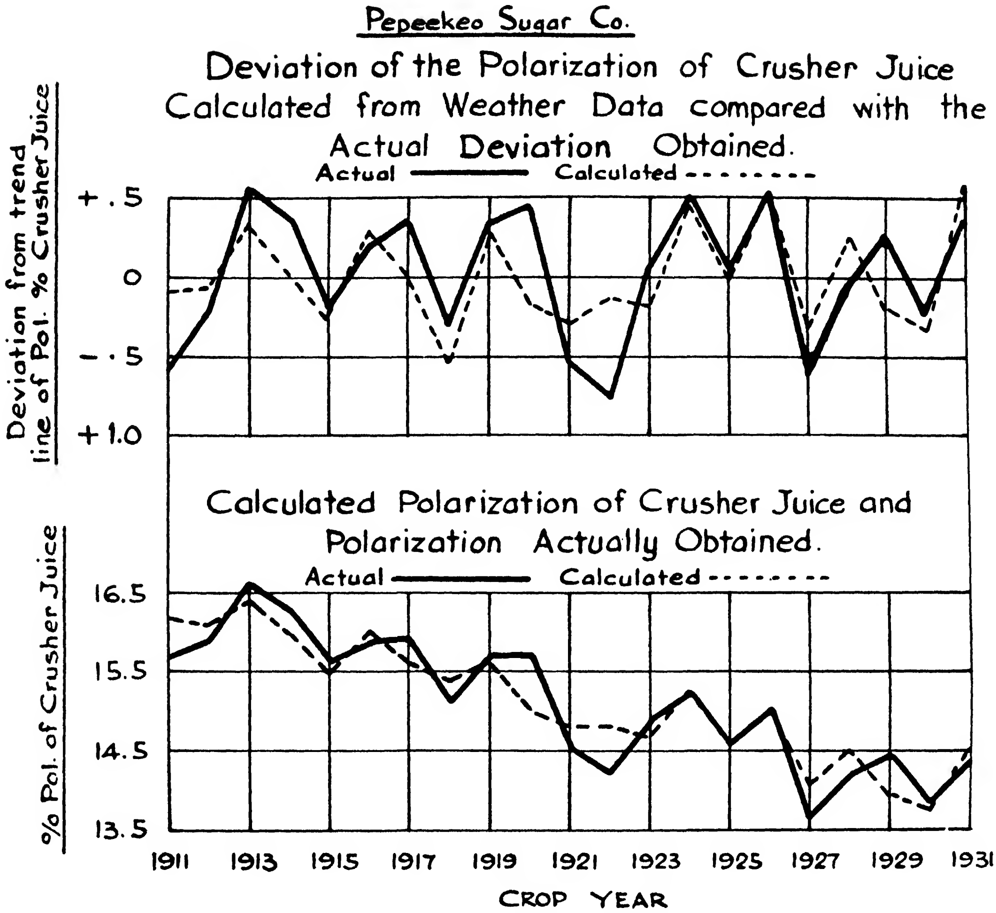


Fig. 8

find that the distribution of rainfall for the crop of 1920 was quite abnormal. Under normal conditions of weather, the sequence of seasons is such that deficiency of rainfall in one season is usually followed by an excess in the other season, so that the sum total for the crops tends to be about the same. However, in the case of the crop of 1920, one dry month followed another for almost a year prior to harvest. Theoretical considerations would suggest that if high rainfall in the second season spring improves juices by withdrawing nitrogen from the soil at an early period, the same effect could be secured by a succession of dry months so that the nitrogen would remain in the soil without being taken up by the cane plant in large quantities and hence doing no harm to the quality of juice. If we eliminate the figures for 1920 as being incomparable with the rest of the period and recalculate the regression equations we find that the accuracy of our estimate is greatly increased.

We offer the following theory as to the effect of rainfall on juice quality at Pepeekeo, and present the same information graphically in Fig. 9:

1. High rainfall in the spring of second season followed by gradually diminishing rainfall ending in a dry grinding season. Excellent juice.

2. A consistently dry season. Good juice. (Probably poor cane yield.)

Pepeekeo Sugar Co.

Diagrammatic Representation of the Influence of Rainfall in the Spring of the Second Season and the Winter of the Harvesting Season.

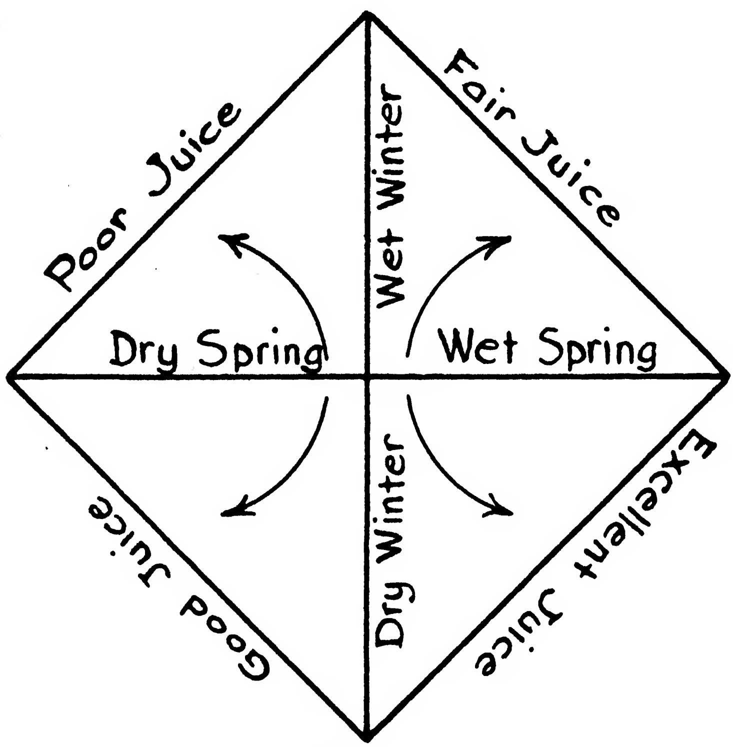


Fig. 9

3. High rainfall in the spring of second season followed by high rainfall in the other seasons including the grinding season. Fair juice.

4. Low rainfall in the spring of second season followed by increasing amounts of rain ending in a wet harvesting season. Very poor juice.

In other words, from the present study we are inclined to think that high rainfall in the second season spring months (under the conditions of our present day field practices) is of greater moment than a dry harvesting season. If the cane has grown vigorously in the spring and summer months of the second season and thereby used up the easily available stores of nitrogen, then it will enter the grinding season in a state of good maturity. Under these conditions a wet grinding season will not cause much damage if a large amount of new growth is not started by a simultaneous occurrence of good growing temperature.

However, this study leaves no room for doubt that at Pepeekeo rainfall is the greatest single factor in causing yearly fluctuations in the quality of juice.

Practical Application of the Results of Weather Studies

The detailed studies of the relation of weather to cane crop do not only furnish us with much valuable fundamental knowledge, but quite often they also suggest possible modifications of field practices whereby greater advantage may be taken of the weather conditions.

In dealing with cane yield, we pointed out the critical importance of the first several months in the life of the cane crop. This would suggest that all our agricultural practices be designed to give the best care and treatment to the crops that are in the first season of growth. Should question arise, as it used to a few years ago, as to which cane should be neglected, there need be little hesitation in choosing to neglect the old cane in preference to the small cane.

Many of us are inclined to think that in a humid district like Pepeekeo with an average rainfall of about 130 inches a year, the moisture requirements of the cane should be amply satisfied. The results of this study show that this is far from the truth and that substantial gains in cane yield could probably be secured if more moisture could be applied to the second season cane in the summer months. However, the practicability as well as the economics of a venture in irrigation (at least on limited areas) must be left to the plantation to decide.

In dealing with the quality of juice, we would suggest that the following modifications be given consideration.

It is the present practice to apply about 75 pounds of easily available nitrogen partly in the month of March and mostly in the month of April of the second season. If the immediately following spring and summer months have well distributed and sufficient rain, the growth of the cane proceeds rapidly and the nitrogen is taken up early in the season. The crop has, consequently, ample time to complete vegetative growth and start maturing. If, on the other hand, rainfall is much below normal, the growth of the crop is slow and the nitrogen stays in the soil. (Some writers (6) suggest that it goes into an organic form during a dry summer to be available again in an inorganic form when the rains come.) Then following a dry spring and summer comes a wet fall or a wet winter, the stores of nitrogen in the soil become available again and the crop puts on a luxuriant growth. But this growth comes too late, the crop has hardly any time to mature before it is being harvested. The question naturally arises: Can we not avoid this state of affairs by taking the weather factors into consideration? These studies suggest two possible ways: First, by applying the second season nitrogen much earlier. But there are reasonable objections to applying nitrogen previous to or during the wet and cold months of January, February and March. Not only are there dangers of excessive leaching, but also it is doubtful if the plant gets full benefit from nitrogen applications in the cold months of the year when growth processes are normally very slow. Second, by modifying our present practice in the following manner: Let us assume that we have decided to apply second season nitrogen not earlier than April. We would then split up our dose of 75 pounds into two lots, one of 50 pounds and another of 25 pounds. We shall apply the first dose in April and if the weather conditions immediately following are favorable to growth, and there is plenty of well distributed rainfall, then we shall apply

the second dose of 25 pounds in June or early July.* With normal rainfall, these and the months following are generally the months of most vigorous growth and, therefore, there will be plenty of time for the cane to assimilate the nitrogen and come to maturity in due course of time.

If, on the other hand, rainfall is far below normal in the months following the spring application and growth of the crop is slow, then we would withhold the second application altogether.

In a season of belated rains shall we not, thereby, prevent the loss of quality in juice and save money in our fertilizer bill as well?

Theoretically there appears no reason to believe that the yield of cane will be materially affected by this modification.

Whether the extra cost of applying the second dose in July will offset the gain in juice quality is still a question to be decided by actual experimentation.

Prediction Value of the Regression Equations

The regression equations developed previously in this study show that at least in the case of the cane tonnage, the probable yield may be estimated with reasonable accuracy several months before the actual harvesting season. The question would be asked: Can this manner of estimating yield replace the present practice of estimating from experience or by the eye alone?

The greatest uncertainty in the use of such an equation would arise from not knowing exactly the direction and magnitude of the future trend. In this study, the trend appears to be continually rising at the average rate of 1.44 tons of cane per acre per year. It is not conceivable that the trend will continue to be the same indefinitely. In fact there are very sound reasons for believing that the trend will or is already flattening out at Pepeekeo. The calculation of actual tons cane per acre from the equation may, therefore, be subject to error. It must be left to the discretion of the people on the plantation as to what value should be given to the trend line.

We believe, however, that if we use these equations to get an idea as to whether our next yield is going to be considerably above, near or below the average, we will find that the accuracy of our estimate will, in general, be better than any other estimate based on experience alone.

For the present, therefore, we do not think that these equations can replace the standing methods of estimating yield, but we strongly believe that these could supplement and aid the methods in vogue.

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* Recent experiments seem to indicate that the total amount of nitrogen at present applied in the Hilo-Hamakua coast plantations may be more than the limit of profitable application. If this is true, the total second season application can be cut down to 50 pounds per acre and then, there need be no occasion to apply a second dose of 25 pounds.

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(4) Yule, G. Udny. 1927. An introduction to the theory of statistics. Chap. XII, pp. 229-253. (Eighth edition, London.)

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APPENDIX—A

DETERMINATION OF THE TREND LINE FOR CANE YIELD (1911-1930)

Crop Year	A Yield of Cane-Tons per Acre	B Years Elapsed Since 1911	dA Deviation from the Mean	dB Deviation from the Mean	dB^2	dA x dB
1911	32.95	0	—14.51	—9.5	90.25	+137.85
1912	34.61	1	—12.85	—8.5	72.25	+109.23
1913	36.57	2	—10.89	—7.5	56.25	+ 81.68
1914	41.46	3	— 6.00	—6.5	42.25	+ 39.00
1915	51.03	4	+ 3.51	—5.5	30.25	— 19.64
1916	40.40	5	— 7.06	—4.5	20.25	+ 31.77
1917	45.40	6	— 2.06	—3.5	12.25	+ 7.21
1918	39.96	7	— 7.50	—2.5	6.25	+ 18.75
1919	37.09	8	—10.37	—1.5	2.25	+ 15.56
1920	42.09	9	— 5.37	— .5	.25	+ 2.69
1921	47.02	10	— .44	+ .5	.25	— .22
1922	47.92	11	+ .46	+1.5	2.25	+ .69
1923	41.29	12	— 6.17	+2.5	6.25	— 15.43
1924	50.12	13	+ 2.66	+3.5	12.25	+ 9.31
1925	60.37	14	+12.91	+4.5	20.25	+ 58.10
1926	58.69	15	+11.23	+5.5	30.25	+ 61.77
1927	61.62	16	+14.16	+6.5	42.25	+ 92.04
1928	59.19	17	+11.73	+7.5	56.25	+ 87.98
1929	60.21	18	+12.75	+8.5	72.25	+108.38
1930	61.17	19	+13.71	+9.5	90.25	+130.25
Mean of 20 years	47.46	9.5			Sum of dB^2=665.0	Sum of (dA x dB)=956.97

$$\text{Slope of the trend line} = +\frac{956.97}{665} = 1.44 \text{ tons cane}$$

Filter Mud and Molasses*

By H. P. Agee

We shall concern ourselves at this time with the use of these materials for agricultural purposes only.

For each 100 tons of cane that we produce we make 2 to 3 tons of filter mud (in extreme cases 4 tons), and 3 to 3½ tons of molasses.

Filter mud contains about 73 per cent of water, ranging as a rule between 68 per cent and 77 per cent, with extremes somewhat beyond the variations named. Filter press cake has a phosphoric acid content of 1 to 2 per cent, a nitrogen content of 0.2 to 0.5 per cent, and a potash content of as low as 0.05 per cent and as high as 0.27 per cent.

Molasses contains from 15 to 25 per cent of water. It has a potash content that varies from about 2 per cent to over 4½ per cent.

The value of filter mud for agricultural purposes is so firmly established that it is carried in trucks or by rail for miles, and on pack mules for considerable distances to be placed on the field.

The value of molasses is so poorly established that when, as at present, the market for this material is weak, thousands of tons of it are put into the sea.

Filter Mud

The value of this material has been established largely by observing enhanced cane growth where it is applied to the fields.

We lack and need specific measure of the good it does (or fails to do) when applied in different quantities in different ways. The irrigation specialists tell us "The key to water economy is water measurement." Any economic handling of a material or commodity is in fact dependent upon measurement. Just as the sciences of chemistry and engineering have dealt so largely with the art of measurement, so, too, must agriculture apply measurement as far as practicable to all its affairs.

There are several ways of applying press mud to the field and these are presented briefly so that they may be discussed.

In general, there is the tendency to favor the poorer fields or the poorer spots with press mud applications as a means of building them up. There is the practice of placing the mud broadcast on the field ahead of the round plowing. There is the practice of making a surface application to fields under ratoon cropping. There is the custom to put it in a furrow and cover it. There is the method of placing the filter mud in the plant cane furrow, covering it lightly with soil and then placing the seed cane over it.

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* Presented at Tenth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 19, 1931.

Irrigated plantations often apply press mud in the irrigation water. W. J. Maze, in a bulletin of the Bureau of Labor Saving Devices, described a method of sluicing the press mud upon the fields of an unirrigated plantation by using the ordinary cane flumes. The Hilo Sugar Company uses this method and claims fine results in reaching areas where otherwise it would be too costly to pack the material.

This appears to be a method that deserves special consideration. Some hold that it has the disadvantage of running the filter mud to the low spots where it is not needed, while others claim that if the head of water is low, as it should be, and the flumes are skillfully handled, the filter mud can be placed where it is wanted.

Perhaps the most important point for us to discuss about filter press mud is its relation to commercial fertilizers. Some plantations reduce the applications of mixed fertilizers or nitrogen dressings where the mud has been applied; others do not.

It is possible that unless we take full account of the fertilizing value of filter press mud, and adjust our commercial fertilizers to conform, we may forego the profit we are accustomed to attach to the use of it.

Molasses

We have a considerable amount of evidence that molasses stimulates cane growth on many soils. Frequently the juices are made poorer and no sugar gains result. Here, too, we need to know more about the relationship between molasses and the other fertilizers we apply. J. N. P. Webster has made an interesting review of the results from various field tests at a number of plantations. His paper, quoting the views of several plantation managers, is presented herewith.

The investigations of the Ewa Plantation Company have been furnished us by George F. Renton. A summary of the work, taken from a report by J. L. Nicoll, follows:

1. In general molasses application reduces juice purity. In cases where added cane tonnage overshadows this juice depression net sugar gains are evidenced.

2. Molasses applied before plowing results in appreciable sugar gains on immediate crop harvest. No further ratoon data have as yet been obtained. Unless new methods of application are devised this system is not practical on field scale.

3. Molasses applied in first irrigation on ratoons gives no sugar gain on first crop harvest and tends towards slight loss. Blotched, unhealthy, yellow, and rich green areas appear soon after the cane sprouts and continue until the cane becomes recumbent and further observation is not possible. No ratoon data have yet been obtained.

4. Molasses applied on young growing cane results in leaf burning, particularly in the wet soil type areas. Juices are depressed on both first crop and second crop harvests. There is, however, a slight gain of sugar over the two crops.

5. Molasses applied on mature cane in the last irrigation before harvest produces no effect on the juices of that same crop at harvest. In the following crop

it produces appreciable sugar gains. No burning of leaves takes place except where stagnant water remains in the furrows following irrigation.

6. Injury to cane and yellowing of leaves is believed to be due to excessive available iron and aluminum.

7. Molasses application particularly relieves chlorotic cane.

8. Growth is materially stimulated by molasses.

9. The moisture-holding capacity of a soil is increased through molasses application.

10. It is recommended that field application of molasses be made in the final irrigation before harvest of an area.

11. It is recommended that further and more accurate tests be installed to fully determine benefits derived from molasses application in last irrigation. Until these data have been secured experimentation along other molasses application lines does not seem advisable.

During the early part of the year, Mr. Renton wrote as follows:

> At present we are applying ten tons of molasses per acre in the last irrigation in some of our fields, before harvest on fields which we are now going to plow, and five tons per acre in last irrigation before harvest on those fields which we expect to ratoon.
>
> We anticipate small gains in sugar yields from these applications and possibly some residual effect from this treatment. We are basing these conclusions on the results of experiments. . . .

E. W. Greene, of the Oahu Sugar Company, has been quoted by Mr. Webster in his paper, to which you are referred. We shall not repeat here except to lend emphasis to his statement:

> We doubt whether good results can be obtained where molasses is put continuously into a large ditch and applied more or less indiscriminately over a group of fields.

Other plantations replied to our inquiries during the year along these lines.

Experience on Maui

Maui Agricultural Company, Ltd.:

> We have had no experience in applying molasses in the fields excepting in the irrigation water, or by waste water, when available, to fallow lands.

(See attached report of Mr. Webster for mention of results of cooperative experiments.)

Hawaiian Commercial and Sugar Company, Ltd.:

(See attached report of Mr. Webster for mention of results of cooperative experiments.)

Pioneer Mill Company, Ltd.:

(See attached report of Mr. Webster for mention of results of cooperative experiments.)

Wailuku Sugar Company:

. . . We have not applied molasses to the fields on a large scale, nor have we carried on any tests that would be of interest to the Association.

Kaeleku Sugar Company, Ltd.:

We have made no experiments or tests with applications of molasses as a fertilizer which would be of any value to you.

Experience on Kauai

Kilauea Sugar Plantation Company:

As for observations on applying molasses on a large scale to the fields, the writer has, for several years, applied it in the main ditches at Pioneer Mill Company with no apparent ill effects. Small reservoirs were made at convenient points along the ditches, near the railroad track. The molasses was dumped into these reservoirs from the tank cars and fed into the ditch at a rate that gave between two and five tons per acre. These reservoirs are very necessary as it was found that without them there was a tendency, at times, for the molasses to become too concentrated, which would invariably result in a severe burn.

As we have received instructions to waste our molasses we are planning to handle it in the same way here. Small reservoirs are being made adjoining each of two main supply ditches, from which the molasses will be applied to the entire area under these ditches.

We are installing two molasses tests in a field to be planted later on in the year. We find that a convenient, accurate method of applying varying amounts is to irrigate it in the old line prior to harvesting, orient the plots and relocate them in exactly the same place after planting.

The Koloa Sugar Company:

. . . with the exception of the past two years when we sold our molasses, all molasses for the past 30 or 40 years has been applied to a certain set of fields in the irrigation water. No deleterious effect can be noted.

McBryde Sugar Company, Ltd.:

We have practically made very few applications of waste molasses on our fields. Several years ago, we applied ten tons of waste molasses per acre on one of our upper fields before plowing, and the soil analysis showed that there was a small percentage increase in potash in that field.

We are not at present contemplating to apply any waste molasses on any of our fields.

Hawaiian Sugar Company:

No real experiments or tests have been made with molasses applications on this plantation.

During the year 1928, the following amounts of molasses had to be used owing to lack of shipping facilities, and this was the only reason for using molasses as a fertilizer.

	Acres	Tons
Field 1, plant crop, 1930	50	1,[illegible]0
Field 4, ratoon crop, 1929	15	[illegible]5
Field 8, ratoon crop, 1929	3	15

This was applied in the irrigation water in each case, and these fields were selected as being convenient for the handling of the tank cars.

We quickly discovered that the application to Field 1 was much too heavy, and the cane was retarded for two or three months. The juices from this part of the field were lower than usual, and also much lower than from the other parts of the field. We figure that no more than 15 tons per acre should be applied in irrigation water.

Since that time we have not used any molasses for fertilizing, but if we should ever have to do so, the only method we would consider is by plowing under by the steam plows.

Kekaha Sugar Company, Ltd.:

So far there has been no experiment along this line here, but plans are being formulated to conduct such an one in the near future.

Experience on Hawaii

Onomea Sugar Company:

Should it become necessary to dispose of our molasses by applying same to our fields, we believe a good plan would be to have a large tank fitted onto an Athay Truss Wagon with creeper tractor wheels and have a tractor handy to pull it into the fields to distribute the molasses and return the wagon to the roads again for a refill. Now, whether the county officials would allow this hauling to be done on the roads or not, we would at least have some tractor or truck with pneumatic tires to haul same on government road.

Even at $5 per ton for molasses, it would be rather expensive to apply 10 tons per acre, counting hauling, etc. This money might be more advantageously spent for other fertilizer ingredients.

Our idea in applying molasses would be to apply it on ratoons where there would be firmer ground for traction and have the molasses piped from tank to each side of row, taking two rows at a time.

This is just a rough outline how it might be handled should it become a regular practice.

Pepeekeo Sugar Company:

. . . regarding molasses we would say that we have not used any as a fertilizer.

Honomu Sugar Company:

We ran two experiments with molaseheake and a 10-ton per acre dose showed a gain of almost half a ton of sugar. This was against the regular plantation fertilizer practice. A treatment of 10 tons of molasheake without fertilizer showed a tremendous loss.

We have observed straight molasses application at the rate of 5, 10 and 15 tons per acre on small plots and cane growth seemed to be sitmulated considerably in each case. We have had no experience in applying straight molasses in large quantities to our fields.

We refer you to Experiment 15M and 16M, 1930 crop, for results of molasheake experiments.

Hakalau Plantation Company:

The gains due to molasheake are substantial, although they are obtained at considerable expense.

Laupahoehoe Sugar Company:

. . . to date we have not experimented in that line.

Paauhau Sugar Plantation Company:

We have no experiments or tests to report upon with molasses applications.

We did, however, make up two real sizable piles of molashcake during 1928. Six hundred and sixteen tons of molasses were put into this pile, or approximately one-third, and approximately 30 tons of mill ashes with about 100 tons of bagasse, the balance being mudpress. The analysis from this mixture will be found in your laboratory No. 7595, dated November 17, 1928. Placing a value of 5 cents per pound for K_2O and P_2O_5, and 20 cents per pound for nitrogen, the elements in this tonnage were calculated to have a value of $8,888.40, or approximately $4.85 per ton of molasses. This material cost us for mixing and applying, $2.53 per ton, no charge being made for the molasses used, made up as follows: $1.16 for mixing and $1.37 for applying.

The fields which received an application of between 5 and 10 tons of this mixture, responded well to the treatment, but we cannot say that they responded any more than they would have done with mudpress only.

Union Mill Company:

We have not had any experiments or tests with molasses application. However, for many years up to crop 1930, our waste molasses was applied to our fields in the irrigation water. As far as the writer has been able to observe, this has had very little effect on the cane yield of these fields.

Hutchinson Sugar Plantation Company:

We do not use molasses as a fertilizer on this plantation.

Hawaiian Agricultural Company:

We would say that we have only upon one occasion used molasses in the field. We got no results from these. This is the only time we used molasses as fertilizer, having had to use it formerly as fuel.

Olaa Sugar Company, Ltd.:

It is believed that on the lower lands of Olaa Sugar Company, where the soil is very shallow, rocky and well-drained, and high in organic matter, molasses applications will do most good when applied to the growing crop. The response to such applications can be noted within two weeks or so, without any depressing effect on the crop preceding the time when response can be noted.

When the molasses was applied two months or so ahead of planting on a field scale and in some observational tests, no response could be noted to these applications.

Heavy applications have been tried in observational tests wherein the molasses was put on the stubble of ratoons with remarkable response, and no ill effect on the cane.

Molasses will stimulate honohono, and on a plantation like Olaa, where this weed is such a problem, stimulants of this sort increase our costs.

Although we believe there is some gain from molasses applications we believe also that the cost of getting equipment sufficient to handle all of our output would be prohibitive at present, at least with us.

Waiakea Mill Company:

No such practice has taken place on this plantation, so we are unable to give you any information relative to this operation.

Experience Abroad

In a letter to E. W. Greene, dated April 14, 1931, John Murray, of Durban, South Africa, contributed the following information on the subject of molasses:

So as to obtain knowledge of the use of molasses, as a fertilizer, I wrote to various men who manage large estates here, and I herewith give their views:

William A. Campbell, managing director, Natal Estates, Limited, Mount Edgecombe, Natal, says:

"We thank you for your letter of the 30th of March, and in reply have to advise you that we have applied molasses as a fertilizer for over 50 years on the estate. There is a certain amount of trouble in getting equal distribution of the molasses on the fields. Our method is to take it out in tanks on wheels especially built for our tramline. The molasses is then run in furrows such as one would irrigate water, and applied to the field at least a month before planting. Taking, for instance, our poor sandy soil which has been completely worked out, and on which no fertilizer seems to be of any use, treacle applied to this type of soil has given phenomenal yields to over 50 tons of cane per acre, where fertilizers have been a complete failure. We find that treacle binds the sandy soil, attracts moisture, and benefits the soil for years to come. A friend of the writer's, Mr. Ebbels, of Mauritius, discovered that treacle had a power of increasing the nitrifying bacterial action (Azota). All fields treated with treacle are wonderfully green in color. Treacle applied on stiff clay lands as compared to sandy soil is a totally different proposition. On stiff clay lands, unless the field is treated a year before planting, it is apt to kill the cane, in that water collects in little hollows, etc., whereas on sandy soil the reverse takes place. The manurial value of our molasses is chiefly in its potash, 4.5 per cent to 5 per cent with a small amount of nitrogen .3 per cent, although the sugars and organic matter can also be reckoned to be stimulants of some value. We set a value on our molasses for one penny to 1½ pennies per gallon for manure purposes. Next to scum cake (double carbonatation) we consider treacle away ahead of any fertilizers. We also find that molasses remains available in the soil over a long period. We do not prepare the soil as a rule with limestone."

Mount Edgecombe Factory turns out approximately 40,000 tons of white sugar per annum, on the double carbonatation system, using about 5 tons of limestone for every 100 tons of cane crushed, so naturally their press cake is valuable. The limestone is good, viz., 97.5 per cent C. a. C.O. 3, .5 per cent iron alumina, .5 per cent magnesian carbonate, 1.5 per cent silica.

Mr. Edward Saunders, the managing director of the Tongaat Sugar Company, Limited, a concern turning out some 45,000 tons of raw sugar per season, says:

"The question of burning molasses is one which I went into very fully some years ago, and I found that there was no practical difficulty in doing so. The only objection to molasses as a fuel was the tendency to form a thick coating on the boiler tubes, otherwise they burnt quite freely.

"On the other side of the question, i. e., their value as a fertilizer, about this there is no question whatever, assuming the actual value delivered on the ground at approximately (1 pound) per ton, purely for their fertilizer contents. One of the difficulties of utilizing them this way is that it becomes very costly to do so, unless you have a system of irrigation and they can be mixed with the water in the furrows, so great is the difficulty of applying them without these facilities that to all intents and purposes it becomes a non-paying process. In the meantime, however, we have no difficulty in disposing of our molasses locally and so long as it is possible to do so, it suits our purpose better than to attempt to use them as a fuel, as bagasse supplies all that is necessary for this purpose."

Mr. H. H. Dodds, the director of the Sugar Experiment Station here, states:

"The Hawaiian people are fortunate in being able to sell their molasses in its original condition from the factory at a satisfactory price, which is apparently by no means the case here. In view of the vast amount of scientific and experimental work in

agriculture of sugar cane that has been carried out in Hawaii for many years and has made them one of the leading countries of the world in such matters, it is rather surprising that they have only discovered since 1922 the value of molasses in the soil. One would have supposed that it would have been more profitable to utilize the valuable fermentable carbohydrate of the molasses and apply the fertilizer elements in the form of dunder after fermentation and distillation had been completed, but it is conceivable of course that alcoholic fermentation may in some way be a benefit to the soil preparatory to planting crops. Most of the sugar soils in this country are more or less acid, ranging from 5.0 to 6.0 pH, but this does not appear to be a serious obstacle to the use of molasses as a fertilizer. We have not been able yet to get round to any fertilizer experiments with molasses at this Station, but hope to be able to do so before long. It is evident that the biological activity of the soil should be studied during the course of such experiments, but without any biochemist on the staff we have not much prospect of being able to do this. I will write you further on this subject.''

Natal is a very hilly country and the transport of the molasses would appear to be a great obstacle to its use as a fertilizer. Could you help in any way to suggest a means of getting it on the fields cheaply?

MOLASSES

By J. N. P. Webster

In the June 10 issue of a memorandum of the agricultural department of the Experiment Station, mention was made of the increased interest in molasses at present, due to its low sale value and the possibility of profitably applying it to fields.

E. W. Greene, manager of Oahu Sugar Company, Ltd., has favored us with his views on the use of molasses applications and we quote from his letter the following:

> We have found that under our conditions 10 to 20 tons of molasses an acre applied before plowing give excellent results. Thirty tons seem to be more than necessary. The best application for ratoons under our conditions is from 3 to 5 tons an acre. More than 5 tons an acre are apt to burn the cane and retard growth. No retardation of growth occurs with us with 3 tons or less in ratoons and the beneficial effect is soon apparent.
>
> Probably the desirable amounts to apply will vary with different conditions on different plantations.
>
> We have found it advisable, in putting molasses on ratoons, to apply a definite amount to one field in one round of irrigation. We doubt whether good results can be obtained where molasses is put continuously into a large ditch and applied more or less indiscriminately over a group of fields.
>
> We believe that there is a long-continued benefit from the application of molasses to fields.

During 1930, a number of experiments were harvested which showed gains in cane tonnage from molasses applications, but in every case there was also an increase in quality ratio, which, unless there was a considerable gain in cane, would tend to offset any benefit from the molasses.

At Olaa Sugar Company gains were experienced in an experiment where molasses was applied up to 15 tons per acre. However, this same experiment in the following crop showed no response from the residual effect of the molasses.

Regarding Experiment F at Waipio, F. C. Denison states:

Ten tons per acre molasses was applied to the 1928 crop in the last irrigation before harvesting.

This application did not affect the 1928 crop, but favorable results were found in the following crop.

In an observation test at Waianae, there were indications of substantial gains of both cane and sugar.

At Pioneer Mill Company, an experiment in which molasses was applied at the rate of 10, 20, 30 and 40 tons per acre shortly after harvest and before plowing, showed gains in sugar in the plant crop up to 30 tons of molasses per acre, while the residual effect in the succeeding crop was found beneficial up to 40 tons of molasses per acre.

In another experiment at Pioneer Mill Company, where 10 tons of molasses per acre were applied in the irrigation water at the start of the crop, H. J. W. Taylor comments:

The two level ditches having received molasses, show up to distinct advantage in every way.

Two observation tests, one at Olowalu Company and the other at Maui Agricultural Company, gave good gains in cane and sugar from applications of about 20 tons of molasses per acre.

At Kilauea, gains in cane and sugar from applications of 10 and 15 tons of molasses were experienced in an experiment, while the application of 5 tons seemed to have a depressing effect.

An observation test recently harvested at Waialua Agricultural Company where applications of 3, 6 and 12 tons of molasses per acre were applied, primarily to determine the relation of brown stripe disease, showed increases in cane and sugar from each of the applications.

In the early part of this year data were requested from the managers of the various plantations in regard to their experience with the use of molasses as a fertilizer, and the following excerpts are made from their replies:

George F. Renton, manager of Ewa Plantation Company, states:

You will note that here at Ewa we find a detrimental effect on juice purities quite consistent, but, on the other hand, cane yields show a noticeable gain.

At Hawaiian Commercial and Sugar Company for the 1929 crop, three test areas were given applications of molasses to determine the reaction. Previous to plowing and planting two of the areas received 30 tons of molasses per acre. At harvest one area showed no gains while the other showed a gain of 24 tons of cane and 2.8 tons of sugar per acre. The third area, in first ratoons, was given an application of 24 tons of molasses per acre in 1927, and at harvest the gain was 12 tons of cane and 1.5 tons of sugar per acre.

F. F. Baldwin states:

> It is realized that no great weight can be given to the above figures since they are from but single level ditch plots. They do substantiate, however, growth observations made during the progress of the crop. In the one case where no yield response was found at harvest, no differences were seen during the growth of the cane.

For the 1930 crop, Mr. Baldwin continues:

> Four hundred and forty-six acres received molasses at an average of 31.2 tons per acre previous to plowing and planting, and 124 acres of first ratoons received molasses at 15.5 tons per acre. With one exception, the fields included in this acreage produced good cane yields compared to their past records. The quality of the juice was not up to past records, however, so that sugar yields were somewhat disappointing. . . .

Two small check areas in this same crop showed gains in cane and sugar from applications of 28 and 32 tons of molasses per acre.

> 1931 Crop—5,075 tons of molasses were applied to 175 acres that were plowed and planted. None of this area has been harvested to date. Observations on a check layout consisting of four treated level ditches against four alternate untreated level ditches would indicate that considerable more cane is to be expected from the treated area (possibly 20 tons). Juice samples indicate that there is good juice quality in untreated plots at this time as compared to treated plots. The field is being left for later harvest with the hope of reducing the tons cane per ton sugar to a minimum.

Commenting on an experiment at Olaa Sugar Company, where molasses was used with mudpress, Raymond K. Conant, research agriculturist, states:

> It is interesting to note that with the exception of the 10-ton molasses plots, molasses and mudpress alone gave handsome gains over mudpress and commercial fertilizer.
>
> Molasses, mudpress and commercial fertilizers gave consistent gains over mudpress and commercial fertilizer. Generally speaking, these gains were no greater than those shown by the molasses plots without commercial fertilizer. The 10-ton molasses plots are the exception again.
>
> The experiment indicates that molasses at the rate of 15 tons per acre when applied in the interlines at the very start of the crop in combination with 12 tons of mudpress per acre applied early, gives better yields than mudpress and commercial fertilizer.

At Onomea Sugar Company, applications of 10 and 20 tons of molasses were applied to second ratoons of Yellow Caledonia for the 1929 crop, in a small experiment. The results showed gains for the molasses applications in cane and sugar and when this was again harvested for the residual effect in the 1931 crop the gains were still apparent.

Commenting upon the use of molasses at Pioneer Mill Company, C. E. S. Burns, manager, states:

> Our first experiments with molasses as a fertilizer were of the observation type. In B-4 Field a very heavy application of molasses was made before the field was plowed. This was estimated at 100 tons per acre. There was very little, if any, response to this treatment in the plant crop (1924), but every ratoon crop since then on the area which received the molasses has greatly outyielded the rest of the field. In Field L-2, which was planted in 1923, we had a molasses and mudpress test. This field is split in half by a straight ditch, one side of which received a very heavy dose of molasses (75-100 tons

per acre) and the other side a heavy dose of mudpress. These applications were made about a year prior to planting. Both treatments gave much heavier yields of cane than the field had ever produced before. . . .

Several plantations have used molasses in combination with mudpress and bagasse, while a good many have never used molasses at all.

From what data we have and with a number of instances where gains have been shown from molasses applications, we might more profitably apply molasses to a greater acreage. Of course, it must be realized that the cost of applying molasses becomes a limiting factor where it has to be hauled to fields by means of tank trucks and then distributed, and this applies particularly to unirrigated plantations. On irrigated plantations the distribution of molasses is not such a factor as the common procedure is to apply it to fields in the irrigation water.

The amount of molasses to apply to a plant or ratoon crop is more or less an open question and the profitable limit will have to be determined experimentally. Applications of 10 to 20 tons of molasses per acre applied to a field previous to plowing and planting is perhaps a fair amount until more is known. The incorporation of molasses in the soil in this manner is probably most satisfactory as the decomposition processes will have advanced considerably before a field is ready to plant. It is well known that seed pieces when germinating in contact with molasses will suffer. For ratoon crops an application of about 3 to 5 tons per acre applied to the side of the stubble or in the irrigation water is perhaps sufficient.

Where molasses is applied it appears that greater attention should be paid to the amount of nitrogen, from commercial fertilizers, which a field is to receive. The complaint most often encountered from applications of molasses is that the juices become poorer, thus offsetting to some extent the gain in tonnage. It is a known fact that to keep the biological activities of the soil in equilibrium a certain amount of nitrogen along with the molasses is necessary. Otherwise the organisms, whose duty it is to decompose the molasses, draw upon the nitrogen of the soil for their life processes and the plants suffer. Thus, if molasses is applied at intervals to a growing crop, without attention being paid to nitrogen requirements, then there will be periods of depressed growth and of good growth noticeable in a crop. The depressed growth is due to the organisms utilizing the nitrogen in the soil and later when they have no further material to feed upon they die and the nitrogen stored up in their bodies becomes available to the plants. The activity of the organisms is also dependent upon weather conditions and thus it can be seen that the nitrogen from their bodies may be available to the plants over a long period of time in unfavorable weather and a short period in favorable weather.

This would indicate that all the molasses should be put on in one early application and not applied at several intervals. Thus if molasses has been applied, say in the irrigation water, to a crop up until it is several months old, there may be conditions such that the nitrogen from the soil organisms will be available to the crop about the time it should normally be ripening off and poor juices will be the result.

It may be that the early application of nitrogen to molasses-treated fields leaving out the spring application, or else reducing this application, will help to improve juices. Or perhaps another method would be to leave out the late summer application of nitrogen in the first year. In practically all the experiments harvested the number and time of application of fertilizer and time of application to treated and untreated plots have been identical. Might this not be a fallacy? What would the differences in yields have been had the time element of the nitrogen applications been taken into consideration in these experiments?

The Distribution of Soil Moisture After Irrigation

By H. R. Shaw

Introduction

The manner and extent of soil moisture distribution after irrigation is of immediate and vital concern in the production of sugar cane from approximately 120,000 acres in the Hawaiian Islands. Large areas of cultivated land are entirely dependent upon artificial applications of water by irrigation during the greater part of the year. The recent extensive development of methods of irrigation designed to increase the efficiency of labor and of water application makes the distribution of soil moisture of even greater immediate importance. In the last analysis the success or failure of any system of irrigation lies in its ability to provide and to maintain a proper distribution of moisture to the root system of the plant.

Investigations in England and the United States (1, 2, 3, 4) indicate that the moisture-holding properties of a soil are intimately connected with the physical texture, and particularly with the colloidal fraction, of the soil type. Recent studies in Hawaii (5, 6, 7) point to the fact that there may be a wide range in the moisture-retaining characteristics of soils within rather restricted areas. Moreover, the soil texture appears to govern not only the amount of moisture which may be held by the soil immediately after irrigation, but also the amount of moisture retained in the soil at the time plant growth is retarded because of an inadequate supply of available water. Hence, it would appear that a knowledge of the total percentage of moisture in a soil at a given time is of little value unless the moisture-holding properties of the soil are also known. The moisture equivalent (8, 9) has been found to be a simple and relatively reliable method of determining the moisture properties of a soil. Veihmeyer, Conrad and Hendrickson (10, 11), in California, have found the ratio between total moisture content and moisture equivalent a useful criterion for determining the distribution of moisture after irrigation. This ratio they have termed the "Relative Wetness" of the soil.

Early studies of moisture distribution in Hawaiian soils by Allen (12, 13, 14) at the Waipio substation indicate that "it is impossible to store in the upper 6 feet of (Waipio) soil more than 4½ inches of water of which, on an average, about 2½ inches are retained by the surface 2 feet of soil; the remainder, some 2 acre inches, being held in the lower 4 feet." Allen also found that practically the same amount of water was retained in the soil regardless of the amount of irrigation water applied, and that 65 per cent of a 9-inch irrigation and 47 per cent of a 6-inch irrigation passes below 6 feet and is lost to the plant.

Laboratory Studies on the Distribution of Moisture in Small Containers

Attempts frequently have been made in soil moisture and physiological investigations to study plant growth in soils purportedly maintained at definite and pre-

determined moisture contents. Thus one encounters references in the literature to comparative studies of plants grown in pot cultures which were "kept at moisture contents of 10, 20 and 30 per cent" or similar ranges of soil moisture. The highest yield of plant material from a pot series of this type is generally inferred to be the soil moisture content most satisfactory for plant growth in the soil type and with the plant species under investigation. The desired soil moisture content is generally obtained by determining the oven-dry weight of the soil in the culture, and by adding to the surface of the soil the quantity or weight of water necessary to bring the mass to the calculated moisture content. In other cases the dry soil and calculated amount of water are mixed thoroughly before being placed in the pot, and the amount of water lost through plant transpiration is added daily to the soil surface so that the same gross weight may be maintained constantly.

Studies at the Waipio substation indicate that although it is possible, with sufficient care and precaution, to prepare a small sample of soil at a predetermined moisture content, it is impossible to attain this objective by adding water to the surface of the soil. It is equally impossible to maintain this moisture content by adding water to the soil surface after moisture at the lower depths has been depleted by plant root action.

Cardboard cylinders (ice-cream cartons) about 4 inches in diameter and 8 inches deep were used in the studies reported here. The interior of each cylinder was coated with paraffine to prevent seepage or evaporation of water. Sifted Waipio soil was oven-dried at 110° C. for 48 hours, after which a definite quantity (1500 grams) was weighed into a container. The weight of water necessary to bring the soil to the desired percentage of moisture was added according to the various methods described below, and the moist soil packed immediately into the cardboard cartons. The cartons were covered and placed in a dark, humid atmosphere for 48 hours in order that the soil and water might come into approximate equilibrium.

The carton was then cut into one-inch increments with a sharp knife, and the soil material from each successive increment was divided into two samples, which were placed in soil moisture tins, weighed, and dried in an electric oven at 110° C. for 48 hours. It was thus possible to determine with a fair degree of accuracy the distribution of moisture throughout the soil mass as well as any departures from the desired soil moisture content.

1. *Water Added to Surface of the Soil:* It was desired to bring the dry soil to uniform moisture contents of 10, 20, 25, 30 and 40 per cent based on the oven-dry weight of soil. With samples of 1500 grams of oven-dry soil, additions of 150, 300, 375, 450 and 600 grams of water to the respective containers were necessary. The oven-dry soil was weighed into the carton and packed as uniformly as possible. The calculated weight of water was added through a 50 cc. pipette to the surface of the soil.

The results of the soil moisture percentages of each sample are shown as follows:

	Carton No. 1		Carton No. 2		Carton No. 3		Carton No. 4		Carton No. 5	
1″	27.5	27.3	31.0	30.7	32.5	32.7	25.9	34.9	38.3	38.1
2″	26.3	25.9	30.8	30.5	32.4	32.8	35.5	33.5	37.6	38.2
3″	17.7	15.1	30.2	30.0	32.6	33.1	33.6	33.8	39.2	39.3
4″	3.7	2.4	27.6	28.1	31.8	31.0	33.4	32.6	42.8	38.8
5″	0.8	0.8	12.9	11.0	27.7	24.5	31.4	28.9	39.7	38.9
6″	0.9	1.1	2.5	2.8	11.2	7.9	24.0	15.5	37.6	37.1
7″	0.0	0.1	1.0	1.5	3.7	5.0	11.1	6.1	35.9	35.1
	"10 Pct."		"20 Pct."		"25 Pct.		"30 Pct."		"40 Pct."	

It is obvious that the distribution of moisture throughout the soil mass when a predetermined weight of water is added to the surface is far from adequate. Apparently a given soil has the capacity of holding around its granular or colloidal structure a certain quantity of water. When the surface increment of dry soil has satisfied its capacity for moisture, water flows by gravity to the next lower soil increment where sufficient moisture is adsorbed to satisfy the capacity of the second increment. This sequence is continued until all of the water is held by the soil. The soil at the lower depths apparently receives little if any water until the adsorbing power of the upper increments has been satisfied.

Hence, when 150 grams of water were added to the soil in Carton No. 1, the supply was apparently great enough to satisfy the water-holding capacity of the first 2 inches and part of the third, while soil at the lower depths increased its moisture content by an insignificant amount. When 300 grams of water were added to the soil in Carton No. 2, the supply was sufficient to satisfy the soil in the first 4 inches and part of the 5th, etc.

The variation in moisture content in the wetted area of the upper horizon may be attributed to uneven penetration of water through the soil packed in small containers. Some of the water undoubtedly followed the walls of the container and thus increased the moisture content of small areas at the lower depths.

The distribution of soil and water throughout the soil mass is shown in the following table. The total amount of dry soil and of water in each increment of depth after sampling is shown in the first two columns. In general, the total weight of dry soil recovered in sampling is very close to the calculated amount although it was impossible to remove every gram of soil from the container in the process of sampling. In the first three cases where small amounts of water were added, the total weight of water recovered is sometimes slightly higher than that calculated. This may be due to the adsorption of water from the atmosphere (hygroscopic moisture) during handling, or to the fact that the soil may not have been completely dried before packing in the container. Whatever the cause of this gain, it is so slight as to be considered insignificant as far as the results of the study are concerned. In the last two cases in which relatively large amounts of water were added, the amount of water actually recovered is less than that calculated. The loss may be attributed partially to the fact that it was impossible to recover all of the soil and water during sampling, and partially to the fact that some water not held in equilibrium with the soil may have leaked fom the container in spite of the precautions taken.

In the third column is given the average per cent moisture of each one-inch increment as obtained by dividing the weight of water recovered by the weight

of oven-dry soil, and multiplying the quotient by 100. In the fourth column is given the volume weight, an indication of the uniformity of packing. This figure is obtained by dividing the weight of oven-dry soil in each increment into the weight of water which would be contained in a volume one inch deep and with an area equal to that of the carton. It will be noted that there is considerable variation in this figure between successive increments due to the difficulty of packing dry soil uniformly. This variation is largely eliminated in studies reported later in this paper in which the soil was moistened before packing.

The last column gives the ratio of the moisture equivalent of a composite sample of the sifted Waipio soil used in this study to the moisture content of each one-inch increment of soil in the container. The moisture equivalent seems to have a rather consistent relationship to the maximum field capacity of a soil. From studies on 28 Hawaiian soils (6) it appears that the maximum field capacity divided by the moisture equivalent gives a factor of approximately 1.1. Hence if the ratio between the moisture content of each one-inch soil increment and the moisture equivalent of that soil approaches the constant 1.1, it is safe to assume that the soil increment in question is close to its maximum field capacity and that the water-adsorbing power of the soil has been satisfied.

In the studies reported here it is apparent that the moisture content of the soil in the upper horizon is essentially at its maximum field capacity. The transition between moist soil and the dry soil of the lower horizon is rather sharp. In the case of Carton No. 5, to which sufficient water was added to bring the soil to a moisture content of 40 per cent, the ratio of moisture equivalent to moisture content is greater than 1.1 throughout the soil mass. This indicates that the soil was at a moisture content greater than its maximum field capacity. This contention is supported by determinations of the value of the maximum field capacity of Waipio soil. The average of over 100 determinations of this value at Waipio is 34.5 per cent.

Based on the results of this experiment, it would appear that each increment of dry soil must be wetted to its maximum field capacity before the next lower increment may receive any significant amount of water. It would follow that it is impossible to bring a soil mass to a uniform moisture content less than its maximum field capacity by adding water to the surface of the soil.

TABLE I

Distribution of Soil and Moisture after Various Amounts of Water had been Added at the Soil Surface

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight	"Relative Wetness" Pct. Moisture ×100÷ M. E. (28.9%)
	Carton No. 1—150 grams water added to 1500 grams dry soil				
1	154.2	42.2	27.4	0.66	95
2	244.6	63.7	26.0	1.05	90
3	248.7	40.7	16.4	1.07	57
4	277.1	8.6	3.1	1.19	11
5	244.7	1.9	0.77	1.06	03
6	222.5	2.1	0.94	0.97	03
7	101.2	0.3	0.30	0.43	01
Total	1493.0	159.5	10.7		
Calculated	1500.0	150.0	10.0		
Difference	—7.0	+9.5	+0.7		

Carton No. 2—300 grams water added to 1500 grams dry soil

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight	"Relative Wetness" Pct. Moisture ×100÷ M. E. (28.9%)
1	208.2	64.2	30.8	0.89	107
2	211.3	64.6	30.6	0.91	106
3	231.4	69.6	30.1	0.99	104
4	234.0	65.1	27.8	1.01	96
5	293.9	34.9	11.9	1.26	41
6	213.5	5.5	2.6	0.92	09
7	104.2	1.2	1.2	0.45	05
Total	1496.5	305.1	20.4		
Calculated	1500.0	300.0	20.0		
Difference	—3.5	+5.1	+0.4		

Carton No. 3—375 grams water added to 1500 grams dry soil

1	211.9	69.0	32.6	0.91	113
2	219.8	71.6	32.6	0.94	113
3	227.5	74.7	32.8	0.98	113
4	259.0	81.1	31.3	1.11	108
5	222.5	57.8	26.0	0.96	90
6	254.7	24.4	9.6	1.09	33
7	90.4	3.7	4.1	0.39	14
Total	1485.8	382.3	25.7		
Calculated	1500.0	375.0	25.0		
Difference	—14.2	+7.3	+0.7		

Carton No. 4—450 grams water added to 1500 grams dry soil

1	200.4	61.3	30.6	0.86	106
2	213.5	73.5	34.4	0.92	119
3	263.3	88.6	33.6	1.13	116
4	244.1	80.4	32.9	1.05	114
5	232.9	70.0	30.1	1.00	104
6	216.6	42.8	19.8	0.93	67
7	119.0	11.0	9.2	1.51	32
Total	1489.8	427.6	28.7		
Calculated	1500.0	450.0	30.0		
Difference	—10.2	—22.4	—2.3		

Carton No. 5—600 grams water added to 1500 grams dry soil

1	195.6	74.6	38.1	0.84	132
2	197.7	74.9	37.9	0.85	131
3	220.9	86.7	39.2	0.95	135
4	249.2	97.5	39.1	1.07	135
5	234.3	91.9	39.2	1.01	135
6	218.2	81.4	37.3	0.94	129
7	168.4	59.8	35.5	0.72	123
Total	1484.3	566.8	38.2		
Calculated	1500.0	600.0	40.0		
Difference	—15.7	—33.2	—1.8		

2. *Water Mixed with Dry Soil:* Although it appears from the results of the preceding study that it is impossible to bring a soil to a uniform predetermined moisture content by adding water at the soil surface, attempts were made to attain such uniformity of moisture distribution by mixing the dry soil and water before placing the soil mass in the container.

The sifted Waipio soil was dried at 110° C. in an electric oven for 48 hours, and 1500 grams of the oven-dried soil were spread on a section of oilcloth. The calculated weight of water necessary to bring the soil mass to a certain moisture content was added through a 50 cc. pipette. The soil and water were mixed thoroughly by hand for at least five minutes. Care was taken to break up small lumps of soil and water which formed very readily. After soil and water were felt to be thoroughly mixed, the mass was placed in the cardboard container and allowed to stand for 48 hours in a humid atmosphere in order that soil and water might reach approximate equilibrium. One-inch increments of soil were then sampled in the same manner as that described in the preceding study.

The danger of having the soil adsorb hygroscopic moisture was increased by this method since the soil was exposed to the air for a longer period, during which it was constantly turned and new granular surfaces were constantly exposed. The difficulty of recovering all of the soil and water was likewise increased since the soil, which became very sticky when the larger amounts of water were added, had to be removed from the oilcloth surface as well as from the walls of the container.

In general, however, the distribution of moisture throughout the soil mass was rather uniform, and may be considered adequate for certain studies which must be conducted at fairly uniform soil moisture contents. The distribution of soil and water is shown in Table II.

TABLE II

Distribution of Soil and Moisture after Various Amounts of Water had been Mixed with Dry Soil

	Carton No. 1		Carton No. 2		Carton No. 3		Carton No. 4		Carton No. 5	
1″			18.8	21.0	23.3	24.9	31.0	31.5	38.6	39.0
2″	10.4	10.2	20.4	20.5	24.7	25.2	30.9	31.4	39.7	39.2
3″	9.9	9.5	20.0	20.0	24.7	25.5	30.4	31.7	41.7	40.6
4″	10.8	10.7	21.1	21.0	25.2	25.7	31.3	30.8	41.1	40.6
5″	10.7	10.7	20.6	21.2	26.1	25.7	32.0	25.1	41.7	41.8
6″	11.2	11.0	20.5	20.9	25.5	25.4	31.2	31.4	42.3	41.3
7″	11.5	11.1	20.4	20.5	26.3	25.4	32.0	31.3	42.0	41.9
8″	10.6	10.9	20.9	20.2	27.0	26.2	32.1	31.9	42.3	42.3
	"10 Pct."		"20 Pct."		"25 Pct."		"30 Pct."		"40 Pct."	

Distribution of Soil and Moisture after Various Amounts of Water had been Mixed with Dry Soil

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight
Carton No. 1—150 grams water mixed with 1500 grams dry soil				
1				
2	113.2	11.6	10.2	1.0
3	228.1	22.2	9.7	1.0

TABLE II—Continued

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight
4	238.4	25.5	10.7	1.0
5	224.1	23.9	10.7	1.0
6	253.4	28.1	11.1	1.1
7	235.6	26.5	11.2	1.0
8	195.7	21.0	10.7	0.8
Total	1488.5	158.8	10.7	
Calculated	1500.0	150.0	10.0	
Difference	—11.5	+8.8	+0.7	
Carton No. 2—300 grams water mixed with 1500 grams dry soil				
1	126.9	24.9	19.6	1.1
2	237.7	48.6	20.4	1.0
3	194.9	38.9	20.0	0.8
4	193.3	40.6	21.0	0.8
5	195.3	40.7	20.8	0.8
6	171.1	35.3	20.6	0.7
7	231.2	47.3	20.5	1.0
8	138.8	28.5	20.5	0.6
Total	1489.2	304.8	20.5	
Calculated	1500.0	300.0	20.0	
Difference	—10.2	+4.8	0.5	
Carton No. 3—375 grams water mixed with 1500 grams dry soil				
1	111.0	26.6	24.0	1.0
2	204.3	50.9	24.9	0.9
3	209.7	52.6	25.1	0.9
4	216.9	55.1	25.4	0.9
5	202.2	52.4	25.9	0.9
6	183.7	46.7	25.4	0.8
7	198.6	51.2	25.8	0.9
8	152.6	40.7	26.7	0.7
Total	1479.0	376.2	25.4	
Calculated	1500.0	375.0	25.0	
Difference	—21.0	+1.2	+0.4	
Carton No. 4—450 grams water mixed with 1500 grams dry soil				
1	142.6	44.5	31.2	1.2
2	185.2	57.7	31.2	0.8
3	227.4	70.6	31.0	1.0
4	195.9	60.8	31.0	0.8
5	213.5	60.8	28.5	0.9
6	196.9	61.6	31.3	0.8
7	191.7	60.7	31.7	0.8
8	111.4	35.7	32.0	0.5
Total	1464.6	452.4	30.9	
Calculated	1500.0	450.0	30.0	
Difference	—25.4	+2.4	+0.9	

TABLE II—Continued

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight
Carton No. 5—600 grams water mixed with 1500 grams dry soil				
1	107.8	41.8	38.8	0.9
2	195.0	76.9	39.4	0.8
3	203.6	83.8	41.2	0.9
4	212.5	87.0	40.9	0.9
5	221.8	92.7	41.8	1.0
6	201.6	84.2	41.8	0.9
7	199.8	83.8	41.9	0.9
8	135.1	57.1	42.3	0.6
Total	1477.2	607.3	41.1	
Calculated	1500.0	600.0	40.0	
Difference	—22.8	+7.3	+1.1	

It should be noted, however, that although it appears possible to bring a soil to any desired moisture content by careful and thorough mixing, it is impossible to maintain this moisture content by adding water to the surface of the soil. Hence, if it were desired to grow a plant in a soil maintained at a constant and uniform moisture content (of, say, 20 per cent), it would be impossible to maintain this moisture content by adding to the surface of the soil an amount of water equivalent to that transpired by the plant.

Table III gives the results of an attempt to raise the moisture content of the soil from 20 per cent to 30 per cent by adding water at the surface of the soil. In this case, a specimen of Waipio soil with a moisture equivalent of 31.8 per cent was sifted, and its residual moisture content determined. Sufficient water was added to bring the soil moisture content on a basis of 1500 grams of oven-dried soil to 20 per cent. The soil and water were thoroughly mixed, and the mass placed in the container where it remained for 48 hours. To the soil surface in the container was added 150 grams of water, which theoretically should raise the moisture content of the soil to 30 per cent. The container again was allowed to stand for 48 hours, after which each soil increment was sampled as in the preceding studies.

It is obvious that a uniform increase in moisture content throughout the soil mass did not take place. The moisture content of the soil in the first 3 inches and part of the 4th was raised to a high moisture content, but the moisture content of the soil in the lower horizon is but slightly, if any, higher than that before irrigation. The fact that the ratio of moisture equivalent (31.8 per cent) to the soil moisture content of the upper horizon is greater than the customary constant of 1.1 may indicate that the soil and water were not yet in equilibrium after 48 hours. In view of the results of the previous studies, however, it seems unlikely that moisture would become uniformly distributed throughout the soil even if allowed to stand a longer time before sampling.

TABLE III

Distribution of Soil and Moisture after Sufficient Water was Added to Soil Surface to Raise Soil Moisture Content from 20 to 30 Per Cent

	Carton No. 1		Carton No. 2	
1″	45.0	44.9	43.5	45.6
2″	42.8	42.5	42.3	42.5
3″	53.2	39.4	38.2	37.6
4″	33.1	30.6	32.9	32.6
5″	29.2	27.6	28.8	26.9
6″	21.8	21.4	21.9	22.0
7″	21.3	21.2	21.3	22.0
8″	21.4	21.1	20.9	21.5

150 grams water added to surface of soil containing 300 grams water

Depth in Inches	Weight of Oven-dry Soil	Weight of Water	Per Cent Moisture	Volume Weight	"Relative Wetness" Pct. Moisture ×100÷ M. E. (31.8%)
		Carton No. 1			
1	116.8	52.5	45.0	1.0	141
2	188.2	80.3	42.6	0.8	134
3	196.7	91.2	46.4	0.8	145
4	208.3	66.5	31.9	0.9	100
5	200.6	57.0	28.4	0.9	89
6	239.8	51.8	21.6	1.0	68
7	170.3	36.2	21.2	0.7	67
8	154.2	32.8	21.3	0.7	67
Total	1474.9	468.3	31.8		
Calculated	1500.0	450.0	30.0		
Difference	—25.1	+8.3	1.8		
		Carton No. 2			
1	113.4	50.4	44.5	0.8	140
2	197.1	83.6	42.4	0.8	133
3	208.5	79.1	37.9	0.9	119
4	187.5	61.4	32.7	0.8	103
5	250.2	69.9	27.9	1.1	88
6	196.4	43.1	22.0	0.8	69
7	195.8	42.3	21.6	0.8	68
8	132.7	28.0	21.1	0.6	66
Total	1481.6	457.8	30.9		
Calculated	1500.0	450.0	30.0		
Difference	—18.4	+7.8	0.9		

Field Studies on the Distribution of Moisture After Irrigation

The studies reported in this paper are of a preliminary nature, and attempt to gain basic information on the manner and extent of soil moisture distribution in varied soil types and under various methods of irrigation. The method followed in these investigations was to irrigate a small area of dry soil. After an

interval of at least 24 hours, narrow trenches were dug to the required depth across the irrigated area. In most cases the line of demarcation between moist and dry soil could be seen plainly. The perimeter of the wetted soil zone was marked by pins in the face of the trench, and the position of each pin recorded and mapped. This method, which has been used successfully in similar mainland investigations (11, 15) was first used in Hawaii by T. K. Beveridge, of the Waimanalo Sugar Company.

Soil moisture samples were taken by pressing the rim of the sample tin into the face of the trench, thus procuring a fairly large sample with a minimum of disturbance or distortion of the soil. Two samples were taken from each position. One sample was weighed within 6 hours from the time of sampling, dried at 110° C. in an electric oven for 48 hours, and the total per cent moisture in the sample determined. The other sample, taken from the same position on the face of the trench, was divided into two parts and the moisture equivalent by the standard centrifuge method (9) determined in duplicate. The "Relative Wetness" or total per cent moisture $\times$ 100 $\div$ moisture equivalent was determined for each set of samples taken. The position on the trench face of each set of samples was recorded and mapped.

This method appears to reduce to a minimum errors caused by variation in the moisture-holding properties of the soil, which may occur within limited areas. The ratio between total moisture content and moisture equivalent rather than the moisture percentage itself is the figure which must be considered in these studies. As has been indicated previously, detailed investigations (6) on 28 distinctive soil types from Maui, Kauai and Oahu indicate that there is a remarkably constant relationship between the moisture equivalent and the total moisture content when the soil is at maximum field capacity shortly after irrigation. This relationship may be expressed as moisture equivalent $\times$ 1.1 = maximum field capacity. Hence, if the "Relative Wetness," or ratio between moisture equivalent and total moisture content multiplied by 100 is between 100 and 110, it is fairly assumed in these studies that the soil is close to its maximum field capacity. If the ratio is considerably higher than 110, it is inferred that the water and soil are not yet in equilibrium. If the ratio is considerably lower than 100, however, it appears evident that the soil in question probably has not received additional moisture from the irrigation and that the moisture content of the soil is below the maximum field capacity.

Moisture Distribution Under Contour Irrigation—Waipio Substation.

In a dry, plowed field at the Waipio substation, a series of three furrows 30 feet long, 5 feet wide from center to center, with ridges 12 to 16 inches high, were prepared. Each furrow was essentially level from end to end. Irrigation water was admitted to the head of each furrow from a tank, the volume of which was known accurately, so that the net application of water to an area 30 feet by 5 feet could be calculated. In each series, water was admitted only to the two outer furrows, the center furrow remaining dry. After an interval of 48 hours, trenches were dug at the head and at the foot of each series of furrows, the line

of demarcation between moist and dry soil plotted, and soil moisture samples taken as indicated in the accompanying graphs.

Fig. 1 indicates the distribution of moisture after a light irrigation of 1.34 acre inches per acre. The wetted zone assumes an elliptical shape with its major axis in a horizontal direction. Although there is little difference in color or texture between surface soil and subsoil in the fine, well-drained Waipio loam, the increased density of the soil below the plow limits appears to be sufficient to check slightly the downward movement of water and to allow a lateral movement for 20 or 30 inches to each side of the center of the furrow. The vertical penetration of water under an application of 1.34 acre inches per acre did not exceed 18 inches below the bottom of the furrow.

Under a somewhat heavier irrigation application of 2.00 acre inches per acre (Fig. 2), the lateral movement of water 48 hours after irrigation was not appreciably greater than that under the lighter application, and in most cases did not exceed 20 to 24 inches from the center of the furrow. Apparently the denser subsoil did not exert a checking effect on the downward penetration of water under the heavier irrigation. The shape of the wetted zone changed considerably under the 2.00 acre inch per acre application. The zone became more cup-shaped in appearance, the lateral movement of moisture was not increased, but the vertical penetration of water increased to slightly over 30 inches below the bottom of the furrow.

A heavy application of 4.00 acre inches per acre to the third series of furrows (Fig. 3) caused the entire furrow to be filled with water. The zone of moisture distribution 48 hours after irrigation is significantly different in shape than the two discussed previously. The general shape of the wetted zone appears nearly circular, the lateral movement increased to 30 or 35 inches, and the vertical penetration was nearly 50 inches below the bottom of the furrow. It is significant to note that it is only in this last case with a heavy application of water that the lateral spread is great enough for the wetted zones to overlap, had the center furrow been irrigated. The vertical penetration of moisture in this case, however, was probably far greater than the roots of any but mature plants could reach. It would seem to follow that in order to obtain a lateral belt of wetted soil entirely across a series of furrows under the contour method of irrigation, that it would be necessary to apply water so heavily that a considerable amount would be lost by deep percolation. It is also worthy of note that in no case did the zone of wetted soil extend far into the ridge between furrows. Soil moisture samples indicate that under the conditions of this experiment no water was added to the ridges by lateral movement or by capillary attraction from the irrigated furrows. It would thus appear that, under prolonged periods of no rainfall, cane "hilled up" on the ridge between furrows must depend on a considerable lateral spread of roots to the wetted zone for its supply of moisture and soluble nutrients.

The soil moisture samples and the "Relative Wetness" ratio between moisture equivalent and total moisture content seems to lead toward several interesting conclusions. The position from which samples for total moisture content and for moisture equivalent determinations were taken from the face of the trench is indicated on the graphs by circles. The figure above each circle is the total per cent

moisture of the soil at that point, the figure below the circle is the average of duplicate moisture equivalent determinations which may be considered an approximate of the maximum field capacity of the soil, and in the center of the circle is given the "Relative Wetness" ratio between the two figures.

It will be noted immediately that the "Relative Wetness" of the soil within the wetted zone is close to 100; in other words, the soil is at its maximum field capacity. There does not appear to be any consistent variation in the value of the ratio from point to point within the wetted zone. In view of investigations elsewhere (10, 11, 15) and the results of laboratory investigations on Waipio soil reported earlier in this paper, it seems fair to assume that each increment of soil in both a lateral and vertical direction must have been wetted to its maximum field capacity before the next increment received any moisture. The ratio of the samples taken just outside the perimeter of the wetted zone is, in general, considerably lower than that within the perimeter, although the positions of the two samples may be separated by but a few inches. The inference may surely be drawn that the soil outside the perimeter of the wetted zone has not received any moisture within 48 hours after the irrigation application has been made. In some cases (see particularly Fig. 1), the "Relative Wetness" of samples outside the perimeter of the wetted zone and generally at the lower soil depths may be relatively high, and indicates in some cases that the soil is at its maximum field capacity. It would seem not unlikely that the soil of the lower horizons may have been wetted by previous rainfall and irrigation, the moisture from which had never been depleted by the root action of the previous crop. This belief seems to be supported by moisture samples taken below the center furrow which was not irrigated, and which bear "Relative Wetness" ratios indicating that the residual soil moisture was already at maximum field capacity.

Role of Capillarity in Soil Moisture Distribution.

For many years the faith of farmers, many scientists, and a large number of agricultural text-books have been firmly pinned on the effectiveness of capillarity in providing a lateral and vertical movement of water through the soil to plants. This movement of moisture, based on the theory of surface tension, popularly is believed to carry water laterally through the soil and vertically against the force of gravity for indefinite distances above the subterranean water table. The general confidence in capillary attraction as a means of conveying water through the soil doubtlessly may be ascribed to laboratory demonstrations of the rise of moisture from a free water surface through small columns of soil. That such a movement of water exists for a limited distance from a free water table cannot be doubted, but that capillary attraction is an effective force in the movement of water from moist to dry soil is now generally discredited, (15, 16, 17, 18, 19, 20, 21, 22). Agricultural scientists from the time of King in 1889 and Loughridge in 1894 to contemporary investigators have shown that the lateral and vertical movement of water by capillarity is extremely limited both in rate and extent, and that its value in supplying water to plant roots, except for a short distance above a free water table, is negligible.

In order to determine if capillarity might be considered as a contributing factor in the distribution of moisture through the Waipio loam reported here, soil moisture samples just outside the perimeter of the wetted zone were taken five days after irrigation. The face of each trench, which had been covered to prevent evaporation, was scoured by a cane knife so that all exposed surface was removed and a fresh soil surface presented for sampling. Soil samples were taken for both total moisture content and moisture equivalent as described previously. The position of each set of samples is shown in Figs. 1, 2 and 3 as a dotted circle, and the results of the analysis shown in the same manner as the previous series of samples.

The "Relative Wetness" ratio of the samples, taken just outside the perimeter of the wetted zone five days after irrigation water was applied to the area, indicates that no movement of moisture had taken place after 48 hours. Although the samples were taken but a few inches from the wetted zone as determined 48 hours after irrigation, the "Relative Wetness" shows that the soil was far below maximum field capacity and had not changed appreciably from that of samples taken in the same relative position three days previously.

From these results, it seems safe to conclude that no significant movement of moisture in either a lateral or vertical direction had taken place in the Waipio soil studied after 48 hours from the time of irrigation. It would appear, consequently, that little reliance may be placed in capillary action as a means of conveying water through a loam soil of the Waipio type.

Distribution of Soil Moisture Under Long-line Irrigation— Waimanalo Sugar Company

In a newly plowed field of heavy brownish-black soil on the plantation of the Waimanalo Sugar Company, a similar investigation on the distribution of soil moisture under long-line irrigation was made. Furrows 300 feet long on a 2 per cent slope were made by hand. The furrows were flat and shallow, the ridges seldom being more than 10 inches higher than the bottom of the furrow. For the purpose of the investigation, the furrows were made 10 feet apart, but are shown on the accompanying graphs as 50 inches from center to center. A normal irrigation application was made by plantation laborers. Measurements by a portable one-foot weir indicated an average net application of about 1.5 acre inches per acre, but there appeared to be some variation in application from furrow to furrow.

Twenty-four hours after irrigation, narrow trenches were dug across the furrows at distances of 50, 150 and 300 feet from the level ditch. The perimeter of the wetted zone, which was clearly visible on the face of the trench in all cases, was marked and plotted, and soil moisture samples were taken in the same manner as that described in the investigation on contour irrigation.

An examination of Figs. 4 and 5 reveals that the shape of the wetted zone under long-line irrigation somewhat resembles that from the light application of water under contour irrigation (Fig. 1). The wetted zone is elliptical in shape with the major axis in a horizontal direction. The vertical penetration under the irrigation given did not exceed 20 inches, and averaged approximately 12 inches

below the bottom of the furrow. A dense subsoil close to the surface apparently encouraged lateral percolation after the light application of water given, but in few cases was the lateral movement over 20 inches, and the average about 15 inches, to each side of the center of the furrow. In no case was the lateral penetration sufficient for the wetted zones of adjacent furrows to overlap even if furrows 50 inches apart were used. It is noteworthy that the distribution of water at various distances from the level ditch is not significantly different, and that the area of moisture penetration seems comparable whether the point examined was 50, 150 or 300 feet from the head of the furrow. In the cases where the wetted zone is relatively small, notably in line 4 at 300 feet, line 6 at 300 feet, line 7 at 50 and 150 feet, line 8 at 150 feet and line 10 at 150 feet, the contributing factor appeared to be an increased slope in the furrow for a short distance rather than the length of the furrow from the level ditch.

An analysis of the soil moisture data supports the general considerations stated earlier in this paper. The "Relative Wetness" of the soil within the perimeter of the wetted zone ranges in most cases from 100 to 110, indicating that the soil is at its maximum field capacity. The fact that the value of the ratio does not vary significantly from point to point within the wetted area seems to show that every increment of soil within the perimeter has been brought to the same degree of wetness before any further movement of moisture has taken place. The ratio between samples taken immediately outside the wetted zone are relatively low, and demonstrate that the soil immediately adjacent to the visible area of moisture distribution is far below its maximum field capacity and in all probability has never received any water from the current irrigation. There is no evidence of any movement of water into the ridges between furrows.

Time was not available for a study of the effect of capillary action on the distribution of moisture in this Waimanalo soil. However, investigations on the moisture distribution 300 feet from the head of the furrow were not made for 96 hours after irrigation. There is no evidence, either from increased spread of the wetted zone or from greater values for the "Relative Wetness" of samples taken a few inches outside the perimeter of the wetted area, to indicate a progressive movement of moisture in any direction. It would be difficult to conceive, therefore, that capillarity might be a potent factor in the movement of moisture from moist to dry soil or in supplying an appreciable quantity of water to plant roots some distance away from the wetted zone.

Distribution of Soil Moisture Under the Border Method of Irrigation—Ewa Plantation Company

Studies of moisture distribution under the border method of irrigation were conducted in a fine, brown loam field of the Ewa Plantation Company. The width of each border was 20 feet, and the length about 1200 feet. The general slope of the borders was about 1.5 per cent. Unfortunately, there was no opportunity to study the moisture distribution after the first irrigation to a dry field as had been the case with investigations under contour and under long-line irrigation reported in this paper. The cane in the area studied was about 5 or 6 feet high,

and had 15 irrigations prior to the period of the investigation. Seven adjoining borders were chosen for the investigation. Borders numbered 2, 4 and 6 were irrigated by plantation laborers who made a normal application of water. The intervening borders remained unirrigated so that a determination of the lateral movement of irrigation water might be made.

Trenches were dug across each irrigated border and for some distance into the unirrigated borders on either side at points 100 feet from the level ditch, at the center of the border about 600 feet from the level ditch, and at a point some 200 feet from the end of the border. The trenches were excavated not sooner than 48 hours after irrigation. It was apparent, from an inspection of the face of each trench, that it would be impossible to determine the exact extent of moisture penetration from the current irrigation as had been done in the previous investigations. It has been found difficult, by those using the border method of irrigation, to vary appreciably the quantity of water applied in each irrigation during the first few months of the crop. The necessity for a complete distribution of irrigation water from side to side on the surface of the border makes it imperative that the irrigation application does not fall below a certain minimum, depending on the soil type, the grade, and the level from side to side of the border, which will insure an adequate distribution of water on the surface of the border. Hence it frequently happens that there is no significant difference between the quantity of water applied in the first irrigation to plant cane and that to the same area some months later when the plant must be consuming a much greater amount of soil water. It would naturally follow that such quantities of water applied in early irrigations and not used by the feeding roots of the plant . :s to the lower soil horizon until each successive increment of soil is filled to its maximum field capacity. As more of such excessive applications of water are made, the water probably percolates through the soil until it reaches the subterranean water table. In view of the preceding evidence on the failure of capillary attraction to convey water for any distance through the soil, it appears improbable that any water penetrating below the normal root range is ever recovered by the plant.

It would thus appear that much of the water applied in early irrigations by the border method may function purely as a mechanical means of distributing the application over the entire surface of the border, and that relatively little of the total water applied may be available to the plant. Such would be the opinion gained from an inspection of the trenches across the borders in this investigation. It was impossible to distinguish the wetted area caused by the current irrigation from that caused by previous applications of water. Although the trenches were dug to a depth of six or seven feet there appeared no change in the relative moistness of the soil, and each increment of soil to an indefinite depth appeared to be at its maximum field capacity. Soil moisture results support this observation. Figs. 6, 7 and 8 show the position of each set of samples with the values for total per cent moisture, moisture equivalent, and "Relative Wetness" as described for the previous investigations. In the vertical soil area immediately below the irrigated bed of the border, the value of the "Relative Wetness" of the soil with but few exceptions lies between 100 and 110, indicating that the entire soil mass to an indefinite depth below the border was at maximum field capacity. It appears

probable that the few exceptions in which the value of the "Relative Wetness" ratio lies between 80 and 100 might be caused by a reduction of soil moisture by the feeding roots of the plant, and are too infrequent to intimate any significant exception to the observations noted. From the low value for the "Relative Wetness" of samples taken below the levee between borders and from the adjacent unirrigated borders, it appears probable that but little lateral movement of moisture took place as the soil at these points is generally below its maximum field capacity. At depths of from 8 to 10 feet in some of the trenches there was evidence of a localized or "perched" water table possibly caused by accumulations of excess water in the subsoil shortly after an irrigation. In such a case, capillary action might be effective in the distribution of moisture for a limited distance above the free water table.

Observations in the trenches 200 feet from the end of the borders indicated that there might be a relatively inadequate distribution of moisture and the formation of a hardpan in the subsoil. Whether the hardpan formation (which was not apparent at other points in the border) might have been caused by an inadequate penetration of water during previous irrigations or whether the inadequate distribution might be caused by the hardpan is difficult to determine. With the technique now used in border irrigation, the water is turned off at the headgate when the advancing sheet of water is yet some distance from the end of the border. It seems not unlikely that there may be a short distance, between the position of the advancing water at the time the suppply was stopped and the point at which the water backs up from the end of the border, at which the penetration of water might be inadequate, and a modification of the colloidal properties of the soil such as to cause a hardpan formation might occur. Such a zone of inadequate penetration near the end of the border is often reflected in reduced cane growth under the border method of irrigation.

Conclusions

The investigations reported here on the soil moisture distribution in three distinct soil types and under three methods of irrigation are of such a preliminary nature that it would be inadvisable and dangerous to attempt to draw definite conclusions from them. The evidence appears sufficient, however, to warrant the following suggestions on this important subject:

1. Some of the factors which appear to have direct bearing on the distribution of soil moisture after irrigation are: the nature, depth and texture of surface soil and subsoil, the slope and gradient of the land, and the depth of the free water table below the ground surface. The nature and depth of the subsoil below the surface appear to have a decided effect on the shape of the wetted zone, particularly after light irrigations.

2. Laboratory studies on a Waipio soil indicate that each increment of soil must be brought to its maximum field capacity (or greatest amount of water that can be held by the soil against the force of gravity) before other increments of soil can be wetted. As a corollary, it would appear that it is impossible to irrigate a soil, whether in the field or in pot cultures, to any moisture content lower than its maximum field capacity.

3. After a light irrigation to a normal loam soil by the contour or the long-line methods of irrigation, the wetted area is elliptical in shape with its major axis in a horizontal direction. With heavier applications of water, the lateral spread of moisture does not increase materially but the vertical penetration increases in rough proportion to the intensity of the application.

4. The soil moisture analyses presented in this paper are based on the ratio between the moisture equivalent, a laboratory determination which appears to be a relatively reliable index of the moisture-holding properties of a given soil, and the total percentage moisture in the same soil. This ratio, termed the "Relative Wetness" appears to be a fair criterion of the degree of moistness in a soil.

5. Evidence from this investigation indicates that the soil at all points within the wetted area caused by the irrigation is at its maximum field capacity. The soil immediately outside the perimeter of the wetted zone is considerably below its maximum field capacity, and in all probability receives no water from the current irrigation. Such evidence supports the results noted in paragraph 2: that each increment of soil must be wetted to its maximum field capacity before other soil increments receive any water.

6. There is no evidence from this investigation to indicate that in a well-drained loam soil there is any appreciable movement of water from moist to dry soil by means of capillary attraction. It is suggested that the effectiveness of capillarity in the movement of soil moisture should not be overestimated.

7. Under the contour and the long-line methods of irrigation, the lateral penetration of water in the soil did not exceed 30 inches and was seldom more than 20 inches to each side of the center of the furrow. It seems probable that "hilled up" cane on the ridges between furrows must depend, during prolonged periods of low rainfall, on a considerable lateral root extension to the wetted area for an adequate supply of soil moisture and soluble nutrients.

8. From studies of an Ewa soil under the border method of irrigation it would appear that the soil mass immediately below the bed of the border and to an indefinite depth was at its maximum field capacity although the lateral spread of moisture appears to be limited. It seems, however, that the quantity of water required for an adequate surface distribution of water under the border method of irrigation may be greater than the requirement of the crop, resulting in accumulations of excess water at the lower soil depths, which may never become available to the plant.

9. The methods of investigation reported in this paper are suggested to plantations interested in the distribution of moisture in their soils under various methods of irrigation as a comprehensive and apparently reliable means of irrigation research.

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Annual Synopsis of Mill Data

By W. R. McAllep and W. L. McCleery

This Synopsis includes operating data for all factories in the Association for the year ending September 30, 1931. These 39 factories produced 99.4 per cent of the total Hawaiian crop. Synopsis data represent the production of 987,314 tons of sugar, an increase of 7 per cent over the previous record of last season.

Following the practice of alternating the factory equipment table and the table of roller grooving and returner bar settings, the former has been included in this Synopsis and the latter has been omitted. Table 3 is given again, but in briefer form, only figures of particular significance in making comparisons being retained. This is a tabulation of true averages for the factories where the control is based on the mixed juice, factories where the basis of control was changed to clarified juice following the introduction of the Petree process being excluded.

As usual, factories are listed in most of the tables according to the average production during the previous five years.

Varieties of Cane

The number of varieties amounting to 1 per cent or more of the crop remains at six, the same as last year. P. O. J. 36 has replaced Badila in the Major Variety Table. P. O. J. 36 has been spread quite rapidly in certain areas, chiefly on Hawaii and Kauai, so that in the six years since its release from quarantine the tonnage has increased to 2.6 per cent of the total. Badila, which appeared as a major variety for the first time last year, has this year supplied slightly less than 1 per cent of the cane harvested. Acreage data indicate that in the next two years the tonnage of Badila should approximate 1 per cent of the total quite closely.

H 109 appears to have reached a maximum. In the past five seasons the proportion has fluctuated between 53.1 and 56.6 per cent, with 54.2 per cent this year. The gradual decline of Yellow Caledonia has continued. This year the per cent was 18.8. Ten years ago it was 45. It is still the leading variety on nine plantations.

D 1135 has increased to 13.7 per cent, a figure slightly higher than has been reported previously. This cane has fluctuated between 10 and 13.7 per cent with a slight upward trend for the past 12 years. It is still the most widely distributed variety, being reported this year from 26 factories. Yellow Tip decreased and Striped Tip increased slightly. The trend for both of these canes appears downward.

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	P. O. J. 36	Striped Tip	Others
H. C. & S. Co.	99	...	1	...	...	...	...
Oahu	90	...	10	...	...	...	...
Ewa	96	...	...	...	...	...	4
Waialua	96	...	3	...	...	...	1
Maui. Agr	100	...	...	...	...	...	...
Pioneer	100	...	...	...	...	...	...
Olaa	...	72	28	...	...	...	...
Lihue	51	...	4	15	13	...	17*
Haw. Sug	94	...	6	...	...	...	...
Honolulu	98	...	...	...	2	...	...
Kekaha	98	...	...	...	...	...	2
Haw. Agr	...	33	51	...	1	...	15
Onomea	...	76	10	9	4	...	1
Hilo	...	88	11	1	...	...	...
Makee	61	9	...	8	9	...	13
Honokaa	2	4	66	...	8	...	20†
Wailuku	87	1	3	...	...	...	9
McBryde	76	3	5	1	1	...	14
Hakalau	...	72	13	15	...	...	...
Laupahoehoe	...	34	54	11	...	...	1
Kahuku	97	3	...	...	...	...	...
Koloa	54	3	...	24	15	...	4
Waiakea	...	99	1	...	...	...	...
Pepeekeo	...	98	2	...	...	...	...
Hamakua	...	17	76	6	...	...	1
Paauhau	...	1	65	7	19	...	8
Hutchinson	...	60	25	...	14	...	1
Kohala (Hawi)	...	...	21	...	2	63	14‡
Honomu	...	79	18	...	1	...	2
Kohala	1	1	20	...	...	16	62§
Kaiwiki	...	9	75	13	...	...	3
Waimanalo	71	...	...	...	20	...	9
Kilauea	4	1	4	20	6	2	63¶
Waianae	100	...	...	...	...	...	...
Kaeleku	...	100	...	...	...	...	...
Union Mill	...	...	17	4	78	...	1
Niulii	...	6	54	5	1	34	...
Waimea	100	...	...	...	...	...	...
Olowalu	92	...	...	...	5	...	3
True Average 1931	54.2	18.8	13.7	3.0	2.6	2.1	5.6
" " 1930	56.6	19.9	12.3	3.5	0.7	1.6	5.4
" " 1929	53.1	21.5	13.0	4.3	0.3	2.1	5.7
" " 1928	54.7	20.7	12.9	4.9	...	2.2	4.6
" " 1927	53.1	23.7	11.8	4.0	...	1.6	5.8
" " 1926	48.7	25.6	12.1	4.5	...	2.1	7.0
" " 1925	42.7	30.7	11.9	2.7	...	2.1	9.9
" " 1924	38.1	32.6	12.0	2.3	...	2.0	13.0
" " 1923	30.7	36.3	11.2	1.2	...	1.6	19.0
" " 1922	21.1	40.3	12.2	2.7	...	1.6	22.1

* Badila, 7%; H 456, 6%
† Uba, 15%
‡ K 107, 13%
§ K 107, 55%; K 202, 6%.
¶ Uba, 28%.

Varieties comprising 1 per cent or more of the crop at any factory, but less than 1 per cent of the total crop, are listed below:

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

1. K 107	6. H 9806	10. UD 1	14. Rose Bamboo
2. Uba	7. K 202	11. Wailuku 4	15. Wailuku 2
3. Badila	8. St. Mex.	12. McBryde 7	16. Nalo 44
4. H 456	9. H 8965	13. McBryde 1	17. D 117
5. P. O. J. 213			

Varieties are listed in the order of their tonnage as reported. Percentages are not given as there are indications that minor variety figures in factory reports are incomplete and that the percentages would be misleading. This list accounts for about 70 per cent of the tonnage listed as "Others" in Table 1.

Lahaina, which dropped out of the major variety classification in 1928, has been omitted from the minor variety table this year. It was reported from two factories, but in neither instance did it amount to 1 per cent of the crop. H 5909 and Manoa 213, previously appearing as minor varieties, are not included this year. Additions are H 9806, Wailuku 2 and Nalo 44. D 117, which was formerly a major variety, is now reported from only one factory, and Rose Bamboo, also a former major variety, is reported from but two factories.

Quality of Cane

The average quality ratio has improved slightly since last season. It is better than in 1927 and the same as in 1928, but considerably poorer than in other years. The improvement over last year is due to a moderate increase in pol, which has more than offset a decrease of .57 in purity.

The first expressed juice purity is now down to 86.47, the lowest figure in four years. Lower purities have been reported in but two previous seasons.

The average fiber has decreased .10. The present figure is close to the minimum reported in the past ten years.

Juice purities have decreased on all of the Islands. Cane pol also has decreased on Kauai, but has increased on each of the other islands. On Oahu the increase in pol has exactly offset the decrease in purity, leaving the quality ratio unchanged. On Hawaii and Maui smaller decreases in purity and larger increases in pol have resulted in better quality ratios. On Kauai the decreases in both pol and purity have resulted in a materially lower quality. We thus have had better cane on Hawaii and Maui, poorer cane on Kauai and the same quality on Oahu. These changes are tabulated below. They are expressed as Yields per cent Cane, calculated on the same basis as quality ratio, for Yield per cent Cane expresses differences in quality more accurately than the reciprocal quality ratio figures.

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1922					
Pol	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.11	7.70	7.99	8.30	8.39
1923					
Pol	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.04	7.86	8.43	8.36	8.50
1924					
Pol	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.78	7.53	8.10	8.06	8.19
1925					
Pol	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.84	7.42	8.12	8.15	8.22
1926					
Pol	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.73	7.36	8.23	8.33	8.24
1927					
Pol	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.73	7.71	8.78	9.11	8.91
1928					
Pol	11.57	14.13	13.09	12.09	12.55
Per cent Fiber	12.58	12.56	12.13	12.82	12.50
Purity 1st Expressed Juice	86.60	88.76	86.84	85.16	86.84
Quality Ratio	9.54	7.55	8.39	9.11	8.72
1929					
Pol	11.80	14.56	13.49	12.64	12.90
Per cent Fiber	12.53	13.24	12.28	12.61	12.62
Purity 1st Expressed Juice	86.65	89.14	87.17	85.97	87.18
Quality Ratio	9.45	7.35	8.14	8.69	8.50
1930					
Pol	11.30	13.77	13.05	12.67	12.49
Per cent Fiber	12.73	12.92	12.35	12.57	12.63
Purity 1st Expressed Juice	86.59	88.60	86.98	86.34	87.04
Quality Ratio	9.84	7.79	8.42	8.55	8.76
1931					
Pol	11.51	14.30	13.17	12.55	12.63
Per cent Fiber	12.52	13.04	11.98	12.75	12.53
Purity 1st Expressed Juice	86.18	88.26	86.31	85.49	86.47
Quality Ratio	9.66	7.52	8.42	8.73	8.72

Note: Quality ratio calculated according to formula in 1931 Methods of Control.

TABLE NO. 3

True averages of all factories except those basing control on clarified juice

	1926	1927	1928	1929	1930	1931
First Expressed Juice—						
Brix	18.24	17.17	17.45	17.76	17.36	17.57
Pol	15.88	14.74	15.08	15.40	15.04	15.13
Purity	87.05	85.84	86.41	86.69	86.68	86.10
"Java ratio"	81.8	81.7	81.6	82.1	81.5	81.8
Mixed Juice—						
Brix	13.65	12.88	13.04	13.29	12.98	13.13
Pol	11.48	10.67	10.89	11.15	10.87	10.93
Purity	84.12	82.88	83.47	83.89	83.73	83.21
Weight % cane	110.10	109.71	109.87	110.18	109.77	110.28
Pol % cane	12.64	11.71	11.96	12.29	11.93	12.05
Extraction	97.27	97.23	97.24	97.28	97.25	97.36
Extraction ratio	21.5	22.1	22.1	21.7	21.8	21.2
Last Expressed Juice—						
Pol	2.06	1.88	1.94	1.99	1.94	2.01
Purity	68.72	67.76	68.39	68.73	68.54	68.19
Imbibition water % cane	32.54	32.04	31.99	32.44	32.15	32.23
Syrup—						
Brix	64.21	62.91	63.05	63.38	64.09	64.16
Purity	85.49	84.54	84.86	85.24	85.17	84.57
Increase in purity	1.37	1.66	1.39	1.35	1.44	1.36
Lbs. avail. CaO per ton cane	1.66	1.52	1.46	1.38	1.30	1.37
Press Cake—						
Pol	2.49	2.22	2.34	2.27	1.82	1.65
Weight % cane	2.63	2.67	2.87	2.87	2.96	2.99
Pol % cane	0.07	0.06	0.07	0.07	0.05	0.05
Pol % pol of cane	0.50	0.49	0.55	0.52	0.44	0.40

YIELD PER CENT CANE

	1930	1931	Difference
Hawaii	10.16	10.35	+ .19
Maui	12.84	13.30	+ .46
Oahu	11.88	11.88	.00
Kauai	11.70	11.46	— .24

These changes are in the opposite direction to those recorded last year. They have not been large enough to alter the usual ranking of the islands in quality of cane.

Fiber has decreased on Oahu and Hawaii. Figures for both islands are the lowest since fairly complete data have been compiled. Fiber has increased on Kauai and Maui; on Maui it is higher than in any previous year except 1929.

The quality ratio formula has been changed slightly in the 1931 Methods of Control. Figures in this Synopsis are on the new basis. The new quality ratios are slightly lower, thus indicating a slightly higher yield. Within the range of figures in Table 2, differences vary from .04 to .08, the larger differences being for the poorer quality cane.

Chemical Control

The trend toward more complete control figures continues. A larger number of factories have reported sucrose, pH, and turbidity data and there have been increases in the number of factories weighing mixed juice and molasses.

The control is on a sucrose basis at 35 factories, or two more than previously. Hawi, Kaeleku, Niulii and Waimea are the only factories remaining where the control is not on a sucrose basis.

Mixed juice is weighed at one additional factory, bringing the total to 37, and leaving only Kohala and Kaeleku that do not weigh mixed juice.

Molasses is weighed at 31 factories, an increase of two. Molasses weights are calculated from measurements at seven factories. One factory only has failed to report either weights or measurements. Molasses data from a second factory, however, have been omitted from the averages as the weights had not been corrected for stock in process.

All factories have reported complete pH data for the first time. Thirty-two have reported the turbidity of clarified juice against 27 last year.

The usual comparisons of boiling house recoveries with calculated theoretical recoveries are in Tables 4 and 5. In considering figures in these tables it is necessary to bear in mind that the calculated theoretical figure for sucrose recovery is slightly lower than what we might term the actual theoretical figure on account of deficiencies in our control methods. Likewise, the calculated theoretical figure for molasses is too high.

The trend in the past 10 or 12 years has been toward higher figures for recovery per cent available. With this trend the number of factories reporting 100 per cent or over on available has steadily increased, a new maximum being reached this year with 29 factories so reporting in Table 4 and 19 in Table 5. The num-

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent pol actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co	93.48	94.46	101.0	88.8
Oahu	91.83	93.62	101.9	89.2
Ewa	92.26	92.90	100.7	95.5
Waialua	91.06	91.57	100.6	85.0
Maui Agr.	92.56	94.03	101.6	85.9
Pioneer	92.16	92.06	99.9	94.4
Olaa	90.93	91.82	101.0	90.2
Lihue	90.76	92.40	101.8	90.7
Haw. Sug	92.75	94.25	101.6	95.1
Honolulu	91.75	91.89	100.2	87.3
Kekaha	90.93	90.68	99.7	89.9
Haw. Agr	91.17	91.14	100.0	94.8
Onomea	91.53	91.93	100.4	89.7
Hilo	90.30	91.12	100.9	92.9
Makee	87.97	88.08	100.1	88.3
Honokaa	88.33	89.05	100.8	90.1
Wailuku	91.63	92.38	100.8	92.5
McBryde	90.94	91.95	101.1	93.6
Hakalau	91.83	92.70	100.9	92.7
Laupahoehoe	92.71	91.90	99.1	87.5
Kahuku	90.40	93.39	103.3	94.1
Koloa	91.33	92.18	100.9	93.7
Waiakea	90.00	90.96	101.1	87.8
Pepeekeo	91.44	92.13	100.8	94.1
Hamakua	91.96	92.39	100.5	93.6
Paauhau	89.67	89.77	100.1	90.3
Hutchinson	90.30	91.68	101.5	90.0
Kohala (Hawi)	88.26	88.27	100.0	74.8
Honomu	91.71	92.57	100.9	93.4
Kohala	90.72	89.99	99.2	91.4
Kaiwiki	90.67	88.81	97.9	100.6
Waimanalo	88.07	89.48	101.6	88.0
Kilauea	84.73	82.84	97.8	74.5
Waianae	91.07	90.25	99.1	85.8
Kaeleku	87.70	86.10	98.2	...
Union Mill	87.91	87.43	99.5	87.7
Niulii	85.06	88.79	104.4	78.8
Waimea	91.25	88.70	97.2	...
Olowalu	89.55	89.74	100.2	97.0

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	93.34	94.00	100.7	84.8
Oahu	92.03	92.48	100.5	86.1
Ewa	92.51	91.94	99.4	97.2
Waialua	91.09	90.49	99.3	84.8
Maui Agr	92.53	93.63	101.2	82.7
Pioneer	92.18	91.14	98.9	96.8
Olaa	90.82	91.15	100.4	87.3
Lihue	90.80	91.33	100.6	85.9
Haw. Sug	92.77	93.25	100.5	90.7
Honolulu	91.83	91.05	99.2	90.7
Kekaha	90.87	90.09	99.1	91.8
Haw. Agr	91.26	90.35	99.0	97.8
Onomea	91.53	91.53	100.0	90.4
Hilo	89.88	90.98	101.2	88.1
Makee	88.23	86.90	98.5	90.6
Honokaa	88.44	88.50	100.1	89.8
Wailuku	91.64	91.62	100.0	91.1
McBryde	91.09	90.90	99.8	93.2
Hakalau	91.86	92.24	100.4	91.5
Laupahoehoe	92.67	91.26	98.5	92.8
Kahuku	90.76	92.05	101.4	88.7
Koloa	91.31	91.41	100.1	91.8
Waiakea	90.12	89.92	99.8	86.8
Pepeekeo	91.42	91.84	100.5	93.7
Hamakua	91.80	91.54	99.7	91.7
Paauhau	89.43	89.74	100.3	89.6
Hutchinson	90.39	90.89	100.6	88.0
Honomu	91.62	91.98	100.4	90.9
Kohala	90.81	89.42	98.5	96.7
Kaiwiki	90.27	88.78	98.3	107.1
Waimanalo	88.11	88.93	100.9	85.6
Kilauea	84.53	82.21	97.3	77.1
Waianae	91.32	89.18	97.7	92.2
Union Mill	87.98	85.71	97.4	89.8
Olowalu	89.30	89.49	100.2	96.0

* Calculated by S. J. M. formula.

[illegible] SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Filter Cake	Commercial Sugar	Final Molasses	Undetermined	Filter Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	4.8	80.5	13.1	1.6	0.58	93.45	5.65	0.32
Oahu	4.7	76.8	16.3	2.2	0.29	92.21	6.86	0.64
Ewa	7.5	74.1	17.5	0.9	0.56	91.43	7.28	0.73
Waialua	3.0	76.4	17.1	3.5	0.16	90.35	7.56	1.93
Maui Agr.	..	82.5	15.0	2.5	...	93.63	6.18	0.19
Pioneer	4.7	75.7	18.2	1.4	0.25	90.91	7.57	1.27
Olaa	4.7	76.4	16.8	2.1	0.57	90.63	8.01	0.79
Lihue	5.2	74.9	17.6	2.3	0.79	90.61	7.90	0.70
Haw. Sug.	2.9	79.4	16.4	1.3	0.12	93.14	6.56	0.18
Honolulu	4.8	76.0	16.9	2.3	0.27	90.80	7.41	1.52
Kekaha	3.9	75.9	18.0	2.2	0.41	89.72	8.38	1.49
Haw. Agr.	2.8	76.6	19.5	1.1	0.28	90.10	8.55	1.07
Onomea	4.2	76.9	17.1	1.8	0.11	91.43	7.66	0.80
Hilo	4.9	74.4	19.1	1.6	0.25	90.75	8.92	0.08
Makee	4.7	69.7	22.3	3.3	0.49	86.47	10.66	2.38
Honokaa	6.3	69.9	21.6	2.2	0.72	87.86	10.38	1.04
Wailuku	5.4	76.6	16.5	1.5	0.53	91.13	7.62	0.72
McBryde	2.6	75.6	20.2	1.6	0.20	90.73	8.30	0.77
Hakalau	4.6	76.9	17.2	1.3	0.17	92.08	7.45	0.30
Laupahoehoe	3.0	78.0	16.5	2.5	0.14	91.13	6.80	1.93
Kahuku	4.8	73.7	20.0	1.5	0.23	91.84	8.20	—0.27
Koloa	5.4	74.0	19.1	1.5	0.63	90.83	7.98	0.56
Waiakea	4.5	73.6	19.0	2.9	0.55	89.43	8.58	1.44
Pepeekeo	5.5	75.0	18.6	0.9	0.27	91.59	8.04	0.10
Hamakua	..	79.3	19.4	1.3	...	91.54	7.52	0.94
Paauhau	4.8	73.8	19.5	1.9	0.54	89.26	9.47	0.73
Hutchinson	6.9	72.0	18.9	2.2	0.21	90.70	8.46	0.63
Honomu	6.7	74.7	17.2	1.4	0.21	91.79	7.62	0.38
Kohala	3.7	75.2	19.4	1.7	0.42	89.04	8.89	1.65
Kaiwiki	3.9	75.2	21.1	—0.2	0.45	83.38	10.42	0.75
Waimanalo	5.4	69.9	21.8	2.9	0.56	88.43	10.18	0.83
Kilauea	5.0	64.0	22.9	8.1	1.76	80.76	11.93	5.55
Waianae	3.8	73.9	19.0	3.3	0.30	88.91	8.00	2.79
Union Mill	5.9	70.7	19.5	3.9	0.70	85.11	10.80	3.39
Olowalu	7.6	70.8	21.0	0.6	0.48	89.06	10.27	0.19

Factory	Cane Sucrose*	MIXED JUICE		SYRUP		SUGAR		Undetermined Loss per 100 Sucrose* in cane
		Sucrose	Gravity Purity	Gravity Purity	Increase in Purity	Sucrose	Sucrose per 100 Sucrose* in cane	
H. C. & S. Co.	15.03	11.93	88.6†	88.6	0	98.10	91.54	0.31
Oahu	13.52	11.68	85.65	86.12	0.47	98.47	90.62	0.63
Ewa	13.22	11.22	83.98	86.23	2.25	98.41	89.94	0.71
Waialua	13.88	12.12	85.7	86.0	0.3	98.38	88.09	1.89*
Maui Agr.	14.88	12.63	86.74†	87.0	0.26	97.92	91.68	0.19
Pioneer	13.93	12.27	84.62	85.9	1.28	98.02	88.95	1.24
Olaa	12.39	11.20	85.6	86.7	1.1	97.95	87.91	0.77
Lihue	12.09	11.10	83.8	85.2	1.4	97.75	87.81	0.68
Haw. Sug.	14.42	12.35	85.41	86.62	1.21	98.32	91.37	0.17
Honolulu	14.34	12.10	86.14	87.7	1.56	100.0	88.89	1.49
Kekaha	13.75	12.57	85.28	86.3	1.02	97.94	87.08	1.44
Haw. Agr.	11.77	10.88	85.33	85.92	0.59	98.15	87.53	1.04
Onomea	11.41	9.92	84.65	86.33	1.68	97.93	89.83	0.79
Hilo	11.24	10.07	83.57	84.52	0.95	97.69	88.77	0.08
Makee	11.67	10.31	82.1	82.88	0.78	97.89	82.97	2.28
Honokaa	9.72	9.86	81.22	83.00	1.78	97.87	83.02	0.99
Wailuku	13.62	11.01	85.7	87.2	1.5	98.12	89.74	0.71
McBryde	12.43	10.58	83.05	84.16	1.11	98.04	88.73	0.75
Hakalau	11.31	9.40	84.27	85.50	1.23	97.00	90.71	0.29
Laupahoehoe	12.10	10.43	86.52	86.96	0.44	98.29	88.30	1.88
Kahuku	11.60	10.32	81.74	83.03	1.29	98.36	89.90	—0.26
Koloa	11.89	10.37	82.76	84.44	1.16	98.27	88.30	0.55
Waiakea	11.98	10.59	83.30	84.39	1.09	98.00	85.97	1.39
Pepeekeo	11.60	10.38	83.14	85.41	2.27	98.38	89.36	0.10
Hamakua	11.82	11.21	85.64†	85.08	—0.56	98.42	88.72	0.91
Paauhau	11.24	9.73	83.66	85.03	1.37	97.73	87.19	0.72
Hutchinson	12.25	10.12	81.36	83.26	1.90	97.12	88.42	0.61
Honomu	11.22	9.89	84.10	85.95	1.85	98.26	88.61	0.36
Kohala	12.77	11.18	84.95	85.95	1.00	97.97	86.71	1.61
Kaiwiki	12.82	11.90	85.78	86.86	1.08	97.87	84.99	0.72
Waimanalo	11.93	9.95	79.98	81.32	1.34	97.16	87.20	0.81
Kilauea	10.96	10.34	79.72	80.56	0.84	97.76	76.90	5.29
Waianae	13.37	11.49	83.6	84.7	1.1	97.80	86.79	2.72
Union Mill	12.26	11.76	85.16	85.87	0.71	97.05	80.21	3.20
Olowalu	13.51	10.57	81.62	84.08	2.46	97.57	87.42	0.19
‡True Average 1931	12.75	11.17	84.74	85.78	1.04	98.05	88.61	0.89
" " 1930	12.67	11.08	85.35	86.49	1.14	98.05	88.90	0.89
" " 1929	13.08	11.44	85.58	86.60	1.02	98.00	88.75	1.05
" " 1928	12.69	11.22	85.15	86.23	1.08	97.86	88.49	1.21
" " 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Pol in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice. ‡ Refinery data from Honolulu not included in averages.

ber of factories reporting excessively high recoveries on available, however, has not increased. We do not know just how much the calculated figure for available is too low, and no doubt there is some variation under conditions at different factories. However, if we arbitrarily place the limit for accurate control figures at 102 per cent recovery on available in Table 4 and 101 per cent in Table 5, we find two instances in Table 4, and three in Table 5, where recoveries on available are above these limits.

The amount of molasses accounted for is 89.0 per cent of the theoretical as calculated in Table 4 and 90.6 per cent of the theoretical as calculated in Table 5. Yearly averages for molasses per cent theoretical have varied but slightly from 90 per cent ever since these figures have been compiled. It is probable that we can accept this figure as approximately the amount of molasses that should be produced under average Hawaiian conditions. Assuming that a range of 5 points on each side of 90 per cent should include reasonably accurate figures, we find that in Table 4 two factories are above and three below this range, against one above and two below last year. In Table 5, six factories are above and four below, against four above and two below last year. It thus seems that molasses data are not quite as consistent as last year.

Table 6 contains gravity solids and sucrose balances for the 35 factories reporting sucrose data. But one factory has reported a negative undetermined loss of sucrose, against two last year. This factory also reported in excess of 101 per cent recovery on available in Table 5. A negative undetermined loss of solids has been reported from one factory.

Table 7 is a compilation of sucrose data with averages for the past six seasons. These data represent 97.3 per cent of the crop.

The average for undetermined loss in Table 7 enables us to correct the undetermined loss figure in the large table. This figure is too low, principally because sucrose in molasses is subtracted from pol entering the process. The undetermined loss in Table 7 is .89; the undetermined loss for the same factories on a pol basis is .07 and the difference between these figures is .82. The average for undetermined loss in the large table is .17. Adding .82 to this fiugre gives a corrected average for undetermined loss in the large table of .99.

Milling

Milling loss has been reduced to a lower point than in any previous season. Although slightly better extractions and extraction ratios were attained in 1920 and 1921, on the basis of milling loss we may conclude that milling has been better than in any previous season. The figure used as a standard for comparison in Java, "Undiluted Juice in Bagasse per cent Fiber," also indicates that milling has been better than in any previous year. Averages for bagasse moisture and bagasse pol are also new records.

It has been more difficult to attain a high quality of work than in 1920 and 1921 when the high point in extraction was reached. Tonnage and tonnage fiber ratios are now approximately one-third higher. Operating at higher capacity has limited the amount of water that can be applied and this is now almost a fifth less

than in those years. Also, cane pol is from .5 to 1.0 lower. On the other hand, carrying heavier pressure has been facilitated by strengthening equipment when replacements have been made and in some instances by new installations. The average pressure reported has increased almost 10 per cent. In general, attaining the present quality of work in spite of adverse factors may be attributed to careful attention to details which has resulted in more effective application of the pressure carried and more effective utilization of the water that can be applied.

In comparison with last year, the average extraction has increased .08 and the average milling loss has decreased .04. Moisture in bagasse has decreased .42 and pol in bagasse has decreased .01. Changes in grinding rate, tonnage fiber ratio, pressure on rollers and imbibition have been small. The average grinding rate has increased for the tenth successive year, the increase being from 51.79 to 52.01 tons. Tonnage fiber ratio is practically unchanged. Pressure per foot of top roller has decreased from 70.6 to 70.3 tons. Imbibition water has decreased from 33.26 to 33.19.

Although extraction has been higher and first expressed juice purity lower, the purity difference between first expressed and mixed juice (Table 3) has decreased from 2.95 to 2.89. The difference is smaller this year than in any season except 1929 when it was reduced to 2.80. While this purity difference is influenced by a number of factors, impurities extracted from field trash and losses of sucrose through bacterial action in mills are probably the principal factors influencing these averages. But little reliable information on changes in the amount of field trash is available so we cannot evaluate the influence of this factor. We do know, however, that much attention has been given to mill sanitation. Usually mills are now kept well washed down. Many pumps for the return of unstrained mill juices have been installed and the corresponding juice screens removed, and in a number of instances, juice pans, etc., have been sheathed with copper. Without doubt, the result of these efforts to reduce losses through better mill sanitation is reflected in the lower present day figures for purity differences between first expressed and mixed juice.

The purity difference between first expressed and last expressed juice has been reduced from 18.42 to 18.23.

A new record has been made in the number of factories reporting under 2.0 milling loss, nine so reporting against eight last year. Nine factories have reported over 98 extraction, a reduction of one from the previous record number of last year.

No new records have been made at individual factories in extraction, extraction ratio or milling loss.

Factories are arranged in the order of their milling loss in Table 8. Waimanalo and Hakalau are in first and second place respectively for the fourth successive year.

Adidtional milling equipment has been installed at Waialua and Honokaa. In each instance another unit has been added, converting these mills to a crusher and 15 rollers. The loss in bagasse has been reduced by slightly less than 30 per cent at each of these factories.

TABLE NO. 8—MILLING RESULTS

Showing the rank of the factories on the basis of milling loss.

Rank	1930 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Imbibition % Cane	Tonnage Ratio	Tonnage Fiber Ratio*
1	1	Waimanalo.....	1.25	10.6	98.59	39.57	1.90	25.3
2	2	Hakalau.......	1.43	12.8	98.49	38.56	1.71	20.2
3	4	Onomea........	1.67	14.7	98.23	34.08	2.23	26.7
4	8	Wailuku.......	1.74	13.0	98.46	41.30	1.28	15.2
5	3	Honomu........	1.77	16.1	98.08	32.42	1.61	19.2
6	5	Ewa..........	1.78	13.7	98.34	37.28	1.64	19.9
7	6	Olowalu.......	1.84	13.7	98.14	47.02	1.45	19.5
8	7	Hilo...........	1.89	16.9	97.80	32.18	1.97	25.6
9	12	Oahu..........	1.99	15.0	98.25	33.51	1.96	22.9
10	15	Paauhau.......	2.03	18.1	97.67	34.80	1.12	14.4
11	13	Kahuku........	2.06	18.1	97.86	29.29	1.64	19.4
12	19	McBryde.......	2.08	17.0	97.76	37.37	1.56	20.6
13	10	Haw. Sug......	2.14	15.0	98.08	35.91	1.86	23.8
14	14	Pepeekeo......	2.19	19.0	97.55	28.17	1.81	23.3
15	9	Pioneer........	2.26	16.5	97.81	35.01	2.36	31.4
16	16	Kohala (Hawi).	2.32	19.0	97.59	26.50	2.13	27.0
17	17	Maui Agr......	2.36	15.9	97.91	38.64	1.83	24.0
18	11	H. C. & S. Co....	2.37	15.6	97.93	44.92	1.60	21.2
19	22	Hutchinson....	2.42	20.0	97.46	39.43	1.82	23.1
20	20	Koloa.........	2.54	21.7	97.19	33.89	1.51	19.5
21	18	Waimea........	2.56	19.1	97.66	33.04	1.68	20.5
22	28	Honolulu......	2.60	18.4	97.87	35.47	1.38	16.0
23	21	Waianae.......	2.82	21.4	97.56	32.34	1.70	19.4
24	32	Waialua.......	2.82	20.6	97.47	34.50	2.54	31.2
25	25	Haw. Agr......	2.85	24.4	97.12	26.54	2.04	24.1
26	35	Hamakua......	2.86	24.5	96.88	24.49	1.51	19.2
27	24	Lihue..........	2.93	24.7	96.86	28.20	2.41	30.6
28	33	Olaa...........	2.97	24.2	96.97	30.30	2.45	30.8
29	23	Kohala........	3.07	24.4	97.36	30.20	1.66	18.0
30	27	Laupahoehoe...	3.08	25.8	96.87	33.13	1.85	22.5
31	26	Kekaha.......	3.29	24.2	97.02	27.97	2.31	28.5
32	34	Waiakea.......	3.60	30.5	96.08	32.32	1.73	22.2
33	29	Kilauea.......	3.77	34.8	95.18	26.64	1.69	23.4
34	30	Makee.........	3.78	33.0	95.88	30.72	2.32	29.0
35	31	Kaiwiki.......	3.91	30.7	96.13	25.78	1.68	21.2
36	38	Honokaa.......	4.05	42.1	94.44	19.25	1.87	24.7
37	36	Kaeleku.......	4.78	40.8	93.95	35.56	1.77	26.3
38	37	Union Mill.....	5.04	41.9	94.12	23.58	1.72	24.1
39	39	Niulii.........	5.78	55.0	92.23	25.11	1.91	26.9

* Tonnage ratio multiplied by per cent fiber in cane.

Boiling House Work

This year it has been necessary to handle lower purity juices in the boiling house, the mixed juice purity being .54 lower than last season, and lower than in any preceding season except 1927 and 1921.

Clarification has been less satisfactory than last season, but better results have been secured in filtration. The low grade work has been better than in any previous year and the deterioration factor also has been reduced to a lower point than ever before.

Clarification:

Both the increase in purity from mixed juice to syrup and the turbidity of the clarified juice are less satisfactory than last year. The increase in purity (Table 3) has dropped from 1.44 to 1.36. The turbidity has dropped from 3.45 to 3.41. Slightly more lime was used and the average pH of the hot limed juice was slightly higher.

Filtration:

The following refers to data in Table 3. Filtration losses have again been reduced. The cake pol is the lowest in ten years and the loss per cent pol in cane is the lowest in seven years. Filtration losses have been reduced at 70 per cent of the larger factories.

Following the trend of recent years, the weight of cake per cent cane has increased. The amount this year, 2.99 per cent, is the highest on record. Cake pol has been reduced from 1.82 to 1.65. This decrease has been sufficient to offset the increase of .03 in weight of cake and to reduce the loss in filter cake per cent pol in cane from .44 to .40. Loss in filter cake reached a maximum of .55 in 1928. Since that time it has been reduced each year.

This year an Oliver-Campbell filter was installed at Kekaha. This filter is of the vacuum drum type, covered with a perforated metal screen. Fine bagasse is added to the settlings as a filter aid. The filter was operated during the last two or three months of the season. The filter cake loss at Kekaha has been close to the average for the Islands in the last few years. When this filter was used, there was little difficulty in cutting this loss in half. Undoubtedly, the results can be improved with further experience. This type of filter has a large capacity and the operation is satisfactory. From present indications, it seems that there is now some prospect of putting the filtration of settlings on an economical and technically satisfactory basis. The first successful operation of a vacuum drum type of filter on settlings in a cane sugar factory was at Oahu in 1926. In the six years since that time, design and practice have developed to the extent that it now seems that a thoroughly satisfactory solution of the filtration problem is in sight.

Evaporation:

The average syrup density has decreased from 64.34 to 64.15. The latter figure, however, is higher than in any year except 1930.

Evaporator capacity has been increased at two factories, Hutchinson and Hawaiian Agricultural Co.

Commercial Sugar:

Pol has again increased slightly, bringing the average from 97.66 to 97.69. The average for the group of factories shipping to Crockett has increased .01; for the other factories the increase has been .12. Averages for the two groups are now 97.78 and 96.96 respectively.

Moisture has been reduced, bringing the deterioration factor to .231, a new record. The deterioration factor has been reduced each year since 1925.

The number of factories reporting average deterioration factors higher than .25 has been reduced from 6 to 3. In 1929 thirteen factories reported in excess of .25.

Low Grade Sugar:

Notwithstanding an improvement in final molasses purity which might be expected to influence the low grade sugar purity adversely, the average purity of the low grade sugar has not decreased. On the contrary there has been a slight improvement, from 75.66 to 75.69.

Final Molasses:

A new record has been made in final molasses purity, the average having been reduced from 36.69 to 36.32. The final molasses purity has been reduced in each year since 1926. Although the molasses purity has been reduced considerably, this improvement has not offset the influence of lower juice purities and both the quantity of molasses and the loss of sucrose in molasses have increased.

Factories are listed according to final molasses purity in the following table:

GRAVITY PURITY FINAL MOLASSES

32–33	
Kahuku	32.37
33–34	
Hamakua	33.21
Ewa	33.39
Koloa	33.54
Haw. Sug.	33.61
McBryde	33.81
34–35	
Pioneer	34.24
Waianae	34.38
Oahu	34.62
Hutchinson	34.69
Laupahoehoe	34.76
Pepeekeo	34.97
35–36	
Hakalau	35.34
Honomu	35.63
Maui Agr.	35.74
36-37	
Waimanalo	36.05
Lihue	36.48
Waiakea	36.56
H. C. and S.	36.62
Haw. Agr.	36.71
Honolulu	36.81
Waialua	36.96
37–38	
Onomea	37.01
Hilo	37.60
Honokaa	37.71
Makee	37.85
38–39	
Kohala	38.10
Olowalu	38.15
Wailuku	38.35
Kekaha	38.72
39–40	
Kohala (Hawi)	39.13
Kaeleku	39.33
Paauhau	39.56
Olaa	39.6
Over 40	
Kilauea	40.51
Kaiwiki	41.42
Niulii	42.39
Union Mill	45.06

The first nine factories are lower in purity than last year and are also lower than in 1929. Twenty-four factories reduced molasses purity while 14 have reported increases. Factories that have reduced molasses purity 1.5 or more are

Waianae, Hawaiian Agricultural Co., Kaiwiki and Hawaiian Sugar Co. There are now only four factories reporting 40 purity or higher, compared with six last year and seven in 1929.

Kahuku is again in first place for the ninth successive year. The record for molasses purity, 31.81, was made at this factory in 1927.

Undetermined Loss:

The average for undetermined loss in the large table has increased from .14 to .17. With these figures corrected as indicated in the discussion of chemical control, the increase is from .98 to .99. This is the first year since 1925 that the undetermined loss average in the large table has not decreased. The undetermined loss on a sucrose basis, Table 7, is the same as last year, .98.

Recovery

Improvements in factory work, discussed in preceding sections, have not been sufficient to offset lower initial purity, and recoveries have decreased; the boiling house recovery from 91.77 to 91.54 and the total recovery from 89.33 to 89.17.

With the same quality of work as last year we would expect a decrease in total recovery of about .44 because of lower initial purity. The actual decrease has been but .16. The difference, .28, may be credited to a smaller decrease in purity from first expressed to mixed juice, higher extraction, a reduction in filter cake loss and lower molasses purity, these improvements being partially offset by a smaller increase in purity in clarification.

Calculations based on quality ratio indicate the same improvement in factory work as control data. After correcting quality ratios for fiber in cane and sugar pol, we find that in 1930 the recovery of sugar was 99.74 per cent of the recovery indicated by quality ratio. This year the recovery was 100.02 per cent, an improvement of .28, which may be credited to better factory work.

Comparison of Actual and Calculated Recoveries

These comparisons are in Table 9. Values assumed in calculating the theoretical recoveries are given in footnotes accompanying the table. As in the past few years no attempt has been made to designate probable inaccuracies in control data. It is possible to exceed 100 per cent recovery on available in either comparison even in the absence of control errors for reasons which have been discussed in previous Synopses.

The two comparisons are being continued in their present form until a better method for comparing factory work is devised. If allowance is made for factors which introduce discrepancies in comparisons of this kind, they give a fair idea of the work of a factory, provided there are no large errors in the control.

Table 10 containing the summary of losses is given in the usual form.

The calculations in this Synopsis have been made by Mr. Brodie, assisted by Mr. Ashton and others of this department.

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

Recovery % Calculated Recovery *					Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
1	Kahuku	97.86	105.94	103.97	1	103.04
2	Oahu	98.25	102.88	101.37	3	101.20
3	Haw. Sug.	98.08	103.01	101.27	2	101.48
4	Waimanalo	98.59	101.94	100.79	13	99.21
5	McBryde	97.76	102.71	100.71	5	100.69
6	Hutchinson	97.45	102.75	100.56	10	99.38
7	Maui Agr.	97.91	102.24	100.52	6	100.47
8	Hakalau	98.49	101.68	100.45	7	100.27
9	Ewa	98.34	101.80	100.39	4	100.81
10	Honomu	98.08	101.49	99.87	8	100.01
11	Koloa	97.19	102.14	99.71	14	99.08
12	Hamakua	96.88	102.33	99.65	19	98.66
13	Pepeekeo	97.55	101.59	99.27	12	99.22
14	Pioneer	97.81	100.96	99.08	16	98.87
15	Onomea	98.23	100.51	99.07	9	99.92
16	H. C. & S. Co.	97.93	100.74	98.92	11	99.37
17	Wailuku	98.46	99.95	98.68	15	99.01
18	Lihue	96.86	101.45	98.67	17	98.82
19	Hilo	97.80	100.62	98.64	21	98.08
20	Waialua	97.47	100.64	98.42	20	98.35
21	Honolulu	97.87	100.14	98.17	18	98.74
22	Waianae	97.56	100.23	98.02	22	97.95
23	Olowalu	98.14	99.42	97.86	26	97.24
24	Haw. Agr.	97.12	100.01	97.45	23	97.43
25	Waiakea	96.08	100.97	97.37	28	96.93
26	Laupahoehoe	96.87	99.98	97.11	24	97.28
27	Olaa	96.97	99.54	96.90	25	97.28
28	Kohala (Hawi)	97.59	98.73	96.71	30	96.29
29	Paauhau	97.67	98.62	96.57	31	95.52
30	Kekaha	97.02	98.81	96.33	29	96.85
31	Kohala	97.36	98.52	96.23	27	96.96
32	Makee	95.88	99.41	95.94	32	94.85
33	Honokaa	94.44	99.97	94.89	34	94.23
34	Waimea	97.66	96.42	94.44	33	94.57
35	Kaiwiki	96.13	96.00	92.59	35	93.30
36	Niulii	92.23	99.37	92.17	36	91.03
37	Kaeleku	93.95	95.94	90.55	38	90.01
38	Kilauea	95.18	93.99	89.98	39	88.92
39	Union Mill	94.12	95.19	89.90	37	90.08

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses.

† The basis of this calculation is 98 extraction, syrup purity one less than the apparent purity of the first expressed juice, sugar purity 98, gravity purity of molasses 33.33 and no other losses.

TABLE NO. 10
SUMMARY OF LOSSES

FACTORY	POUNDS POL PER TON OF CANE: Bagasse	Filter Cake	Molasses	Undetermined	TOTAL	POL PER 100 CANE: Bagasse	Filter Cake	Molasses	Undetermined	TOTAL	POL PER 100 POL OF CANE: Bagasse	Filter Cake	Molasses	Undetermined	TOTAL	Syrup Purity	FACTORY
H. C. & S. Co.	6.2	1.6	16.6	—0.6	23.8	0.31	0.08	0.83	—0.03	1.19	2.07	0.57	5.58	—0.19	8.03	87.99	H. C. & S. Co.
Oahu	4.6	0.8	18.2	—1.6	22.0	0.23	0.04	0.91	—0.08	1.10	1.75	0.29	6.84	—0.59	8.29	85.07	Oahu
Ewa	4.4	1.4	19.0	—0.8	24.0	0.22	0.07	0.95	—0.04	1.20	1.66	0.56	7.26	—0.31	9.17	84.94	Ewa
Waialua	7.0	0.4	20.4	2.0	29.8	0.35	0.02	1.02	0.10	1.49	2.53	0.16	7.48	0.72	10.89	85.1	Waialua
Maui Agr.	6.2	...	18.0	—0.8	23.4	0.31	...	0.90	—0.04	1.17	2.09	...	6.09	—0.24	7.94	86.27	Maui Agr.
Pioneer	6.0	0.6	20.6	0.8	28.0	0.30	0.03	1.03	0.04	1.40	2.19	0.24	7.50	0.25	10.18	85.09	Pioneer
Olaa	7.4	1.4	19.2	0.2	28.2	0.37	0.07	0.96	0.01	1.41	3.03	0.56	7.85	0.04	11.48	86.0	Olaa
Lihue	7.4	1.8	18.6	—1.2	26.6	0.37	0.09	0.93	—0.06	1.33	3.14	0.78	7.77	—0.47	11.22	84.3	Lihue
Haw. Sug.	5.4	0.4	18.6	—2.6	21.8	0.27	0.02	0.93	—0.13	1.09	1.92	0.12	6.53	—0.90	7.67	85.77	Haw. Sug.
Honolulu	6.0	0.8	20.8	...	...	0.30	0.04	1.04	...	...	2.13	0.27	7.31	...	...	86.8	Honolulu
Kekaha	8.2	1.0	22.4	2.2	33.8	0.41	0.05	1.12	0.11	1.69	2.98	0.40	8.22	0.79	12.39	85.48	Kekaha
Haw. Agr.	6.8	0.6	19.6	0.4	27.4	0.34	0.03	0.98	0.02	1.37	2.88	0.28	8.39	0.19	11.74	85.12	Haw. Agr.
Onomea	4.0	0.2	17.2	0.8	22.2	0.20	0.01	0.86	0.04	1.11	1.77	0.11	7.57	0.35	9.80	85.57	Onomea
Hilo	5.0	0.6	19.6	—0.2	25.0	0.25	0.03	0.98	—0.01	1.25	2.20	0.24	8.78	—0.12	11.10	84.08	Hilo
Makee	9.4	1.2	23.8	2.2	36.6	0.47	0.06	1.19	0.11	1.83	4.12	0.48	10.40	0.98	15.98	81.7	Makee
Honokaa	10.8	1.2	19.0	0.8	31.8	0.54	0.06	0.95	0.04	1.59	5.56	0.68	9.90	0.37	16.51	82.03	Honokaa
Wailuku	4.2	1.4	20.4	—0.4	25.6	0.21	0.07	1.02	—0.02	1.28	1.54	0.53	7.61	—0.14	9.54	86.2	Wailuku
McBryde	5.4	0.4	20.2	—1.0	25.0	0.27	0.02	1.01	—0.05	1.25	2.24	0.19	8.23	—0.37	10.29	83.22	McBryde
Hakalau	3.4	0.4	16.6	—0.6	19.8	0.17	0.02	0.83	—0.03	0.99	1.51	0.17	7.42	—0.24	8.86	84.49	Hakalau
Laupahoehoe	7.6	0.4	16.0	2.8	26.8	0.38	0.02	0.80	0.14	1.34	3.13	0.14	6.64	1.19	11.10	86.32	Laupahoehoe
Kahuku	4.8	0.6	18.6	—4.0	20.0	0.24	0.03	0.93	—0.20	1.00	2.14	0.23	8.17	—1.72	8.82	81.68	Kahuku
Koloa	6.6	1.4	18.4	—0.6	25.8	0.33	0.07	0.92	—0.03	1.29	2.81	0.61	7.85	—0.30	10.97	83.70	Koloa
Waiakea	9.2	1.2	19.8	0.6	30.8	0.46	0.06	0.99	0.03	1.54	3.92	0.54	8.37	0.27	13.10	83.38	Waiakea
Pepeekeo	5.6	0.6	18.2	—0.6	23.8	0.28	0.03	0.91	—0.03	1.19	2.45	0.27	7.89	—0.24	10.37	84.62	Pepeekeo
Hamakua	7.2	...	17.2	0.0	24.4	0.36	...	0.86	0.00	1.22	3.12	...	7.39	—0.01	10.50	84.43	Hamakua
Paauhau	5.2	1.2	20.8	1.4	28.6	0.26	0.06	1.04	0.07	1.43	2.33	0.53	9.33	0.61	12.80	84.14	Paauhau
Hutchinson	6.2	0.4	20.2	—0.6	26.2	0.31	0.02	1.01	—0.03	1.31	2.54	0.21	8.34	—0.25	10.84	82.37	Hutchinson
Kohala (Hawi)	5.8	1.0	21.4	6.4	34.6	0.29	0.05	1.07	0.32	1.73	2.41	0.38	8.78	2.62	14.19	82.75	Kohala (Hawi)
Honomu	4.2	0.4	16.8	—0.6	20.8	0.21	0.02	0.84	—0.03	1.04	1.92	0.20	7.55	—0.27	9.40	85.24	Honomu
Kohala	6.6	1.0	22.2	2.4	32.2	0.33	0.05	1.11	0.12	1.61	2.64	0.41	8.75	0.96	12.76	85.01	Kohala
Kaiwiki	9.8	1.2	25.6	1.6	38.2	0.49	0.06	1.28	0.08	1.91	3.87	0.43	10.07	0.64	15.01	86.34	Kaiwiki
Waimanalo	3.4	1.2	24.0	0.4	29.0	0.17	0.06	1.20	0.02	1.45	1.41	0.55	10.16	0.15	12.27	80.33	Waimanalo
Kilauea	10.4	3.6	24.8	10.0	48.8	0.52	0.18	1.24	0.50	2.44	4.82	1.69	11.46	4.59	22.56	80.0	Kilauea
Waianae	6.4	0.8	21.0	4.0	32.2	0.32	0.04	1.05	0.20	1.61	2.44	0.30	7.95	1.54	12.23	83.37	Waianae
Kaeleku	14.2	2.8	...	30.2	47.2	0.71	0.14	...	1.51	2.36	6.05	1.18	...	12.90	20.13	82.06	Kaeleku
Union Mill	14.2	1.6	25.0	3.2	44.0	0.71	0.08	1.25	0.16	2.20	5.88	0.68	10.38	1.37	18.31	85.11	Union Mill
Niulii	16.4	3.2	20.8	0.6	41.0	0.82	0.16	1.04	0.03	2.05	7.77	1.56	9.88	0.28	19.49	81.46	Niulii
Waimea	6.2	1.6	...	29.2	37.0	0.31	0.08	...	1.46	1.85	2.34	0.59	...	10.97	13.90	85.39	Waimea
Olowalu	5.0	1.2	27.2	—0.4	33.0	0.25	0.06	1.36	—0.02	1.65	1.86	0.46	10.14	—0.11	12.35	83.54	Olowalu

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
SEPTEMBER 17 TO DECEMBER 15, 1931

Date		Per Pound	Per Ton	Remarks
Sept.	17, 1931	3.40¢	$68.00	Cubas.
"	22	3.39	67.80	Cubas, 3.38, 3.40.
"	23	3.4217	68.43	Cubas, 3.415, 3.42; Porto Ricos, 3.43.
"	28	3.40	68.00	Cubas.
Oct.	2	3.43375	68.68	Philippines, 3.415; Cubas, 3.43, 3.44, 3.45.
"	5	3.45	69.00	Cubas.
"	6	3.44	68.80	Cubas, Porto Ricos.
"	7	3.45	69.00	Porto Ricos.
"	8	3.435	68.70	Cubas.
"	15	3.40	68.00	Cubas.
"	19	3.42	68.40	Cubas, Porto Ricos.
"	20	3.40	68.00	Cubas, 3.42, 3.40, 3.38.
"	22	3.36	67.20	Cubas.
"	29	3.42	68.40	Cubas.
"	30	3.40	68.00	Cubas.
Nov.	4	3.42	68.40	Cubas, Porto Ricos.
"	6	3.385	67.70	Cubas, 3.39, 3.38.
"	13	3.395	67.90	Cubas, 3.40, 3.39.
"	14	3.38	67.60	Cubas.
"	17	3.37	67.40	Cubas.
"	19	3.36	67.20	Philippines.
"	21	3.30	66.00	Porto Ricos.
"	25	3.28	65.60	Cubas.
"	27	3.25	65.00	Cubas.
"	30	3.21	64.20	Porto Ricos.
Dec.	1	3.20	64.00	Cubas.
"	7	3.15	63.00	Cubas.
"	9	3.125	62.50	Cubas, 3.13, 3.12.
"	10	3.105	62.10	Cubas, 3.11, 3.10.
"	11	3.10	62.00	Cubas.
"	15	3.12	62.40	Cubas.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXVI SECOND QUARTER, 1932 No. 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Changes in Cane Quality:

Data on cane quality of the different plantations over a series of years are presented in compact form in an arrangement that admits of ready comparisons.

Corn Oil for Thallium Wheat Torpedoes:

This paper gives the details of a series of small experiments to determine the desirability of corn oil to make thallium wheat torpedoes more attractive to rats.

Rats showed a decided preference for corn oil over sunflower oil, coconut oil, or paraffine as a material to saturate the paper torpedoes.

In a test at Kailua, about three corn-oiled torpedoes were taken to each paraffine-dipped torpedo.

It was found that the torpedoes continued to be attractive when they were dipped in a mixture of one part of corn oil to three parts of paraffine by weight. This treatment offers the best practical method of combining corn oil with paraffine for waterproofing thallium wheat torpedoes.

Distribution of Soil Moisture Under the Border Method of Irrigation:

Further investigations on the lateral and vertical penetration of soil moisture under the border method of irrigation at the Ewa Plantation Company are reported in this issue. The results indicate the effect of ground slope and the amount of surface application on the subsequent distribution of soil moisture.

Forest Insects on Hawaii:

Mr. Swezey gives an important detailed account of the insects found on or associated with the living, dying and dead native trees of a portion of the large belt of windward Hawaii which has never been previously explored for insects.

Of particular interest are the observations on the insects attached to the dying and dead koa trees. These insects only begin their attacks after the trees or branches are dead or dying from other causes. A superficial conclusion that the insects were the original cause of this condition is usually reached by uninformed persons.

Leaf Scald Disease of Sugar Cane in Hawaii:

This paper records a study of leaf scald disease as it occurs locally. This disease, which has caused significant losses to the sugar industry of Java and Australia, particularly through the elimination of desirable varieties, appears to have been present in obscure form in the Islands for several years. On certain of the Hawaiian varieties, particularly of the Manoa series, unmistakable symptoms occur which permit identification of the disease. Two forms of the disease, the chronic and the acute, occur, the symptoms of which are detailed and illustrated to facilitate identification of the disease.

Of the eight more important cane diseases described in the literature, leaf scald and mosaic are the only two now known to occur in Hawaii.

Among the subjects presented are the following: Geographical distribution, nature of the causal bacterium, results of inoculation experiments, histology, varieties affected and resistance of varieties, mode of transmission and control.

Leaf scald disease seriously impairs the value of the more susceptible cane varieties, but thus far it has been almost entirely confined to test plots of locally developed varieties and appears to be of minor importance to the sugar industry of Hawaii. Its potential significance in relation to present and future commercial cane varieties is not to be underestimated.

Study of Correlation Between Cane Yields and Quality Ratio of Irrigated Cane:

A study of the correlation between the cane yields and the quality ratio of irrigated cane, made from a series of experiments that have been conducted over a period of six years at Waialua Agricultural Company and the Waipio substation, indicates that direct cause and effect relations between these two factors have not been definitely established.

Dwarf Disease of Sugar Cane:

An illustrated article by Arthur F. Bell, pathologist of the Bureau of Sugar Experiment Stations, Queensland, describing this new disease of cane in the Mackay district, is reprinted in full. This apparently serious disease of the variety P. O. J. 2714 has features in common with Fiji, sereh and streak diseases. The origin and cause of dwarf disease have not been determined.

The Cane-Killing Weed:

Arthur F. Bell and W. Cottrell-Dormer, of the Bureau of Sugar Experiment Stations, Queensland, recount the history and distribution of three distinct species of parasitic weeds of the genus Striga, in a paper reprinted under the above title. These weeds are annuals which are propagated by small, light seeds, easily carried by the wind and by the drainage and irrigation water. They are not known to be present in Hawaii. As a rule the areas of cane affected are roughly circular in shape, with a diameter of a few yards. The damage ranges from a barely perceptible stunting to a premature death of the cane.

Changes in Cane Quality

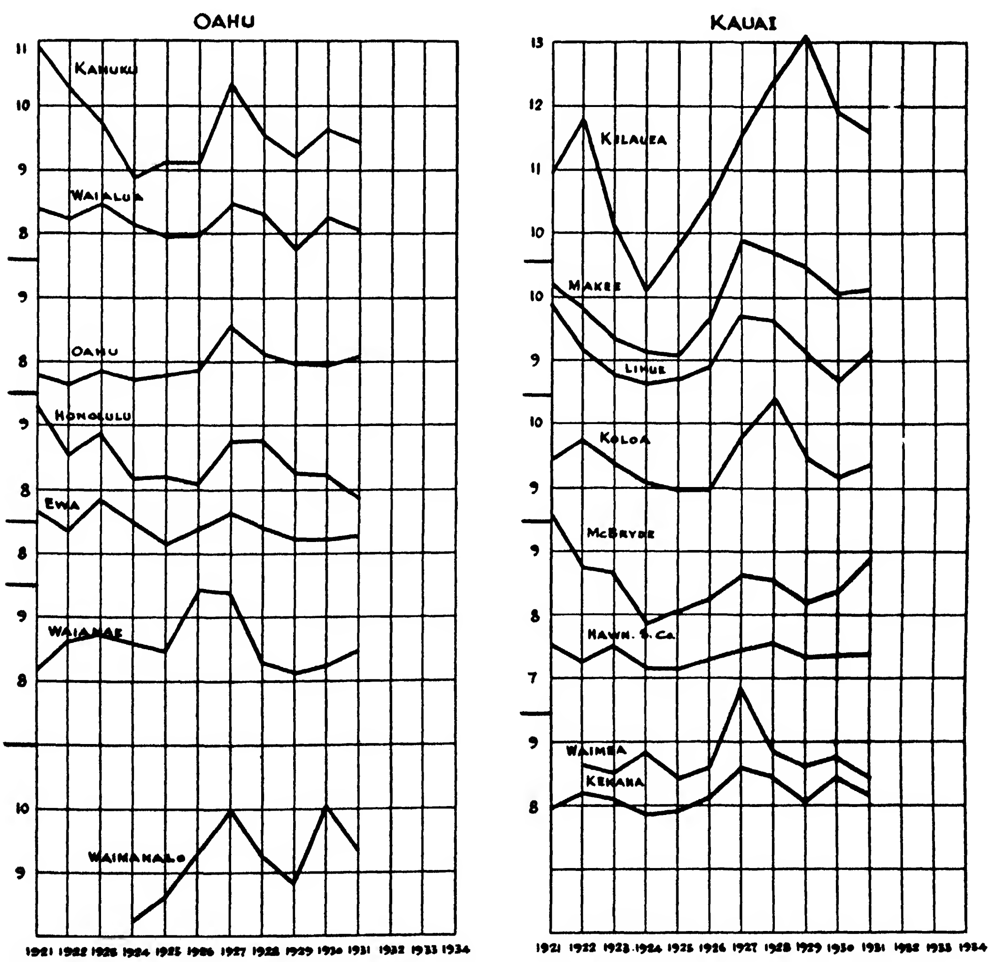
By Ralph J. Borden

The accompanying illustrations, showing the tons of cane per ton of commercial sugar, are made up from the data in the official mill reports of plantations, 1924 to 1931, inclusive. The arrangement, in approximate geographical order, offers a most interesting study. A table showing the changes that took place at each plantation over a ten-year period is also offered.

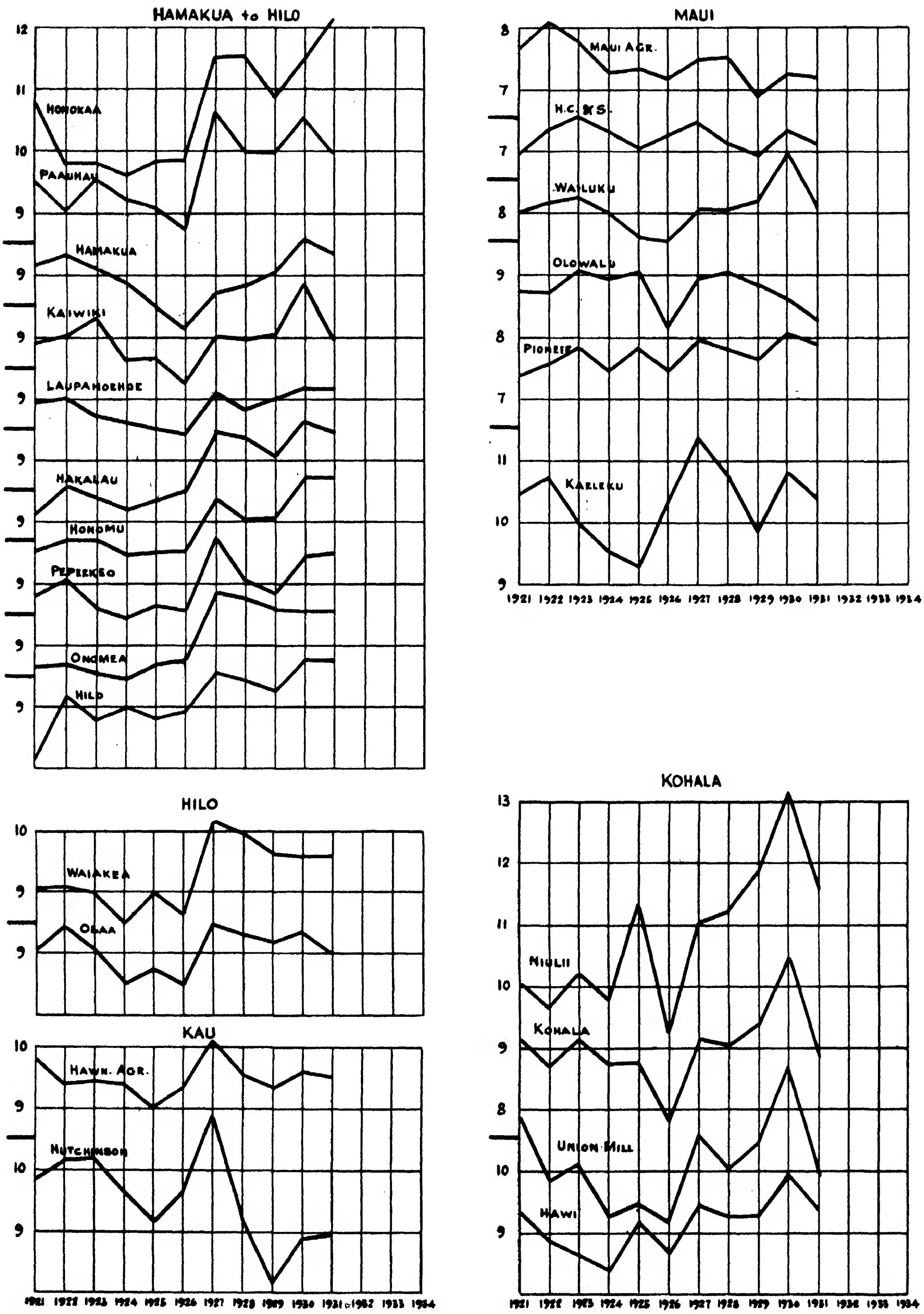
Consideration of the many varietal, cultural, and other differences that exist on the plantations, makes it appear that some other factor, perhaps weather, has been the controlling influence on cane quality. Exceptions to the general trend in any one year are evident and inveigle one's curiosity to know what factors in such exceptional cases may have assisted or antagonized the weather in its effect on cane quality.

TC/TS FOR ALL PLANTATIONS — CROPS 1921-1931 (incl.)

ARRANGED BY GEOGRAPHICAL DISTRICTS



TC/TS FOR ALL PLANTATIONS - CROPS 1921-1931 (Incl.)
ARRANGED BY GEOGRAPHICAL DISTRICTS



CHANGES IN CANE QUALITY

Better (+) or Poorer (—) Juices and TC/TS Amount of Difference Between Consecutive Years

Plantation	1921 and 1922	1922 and 1923	1923 and 1924	1924 and 1925	1925 and 1926	1926 and 1927	1927 and 1928	1928 and 1929	1929 and 1930	1930 and 1931
	Between the Years									
Niulii	+ .4	— .6	+ .5	—1.7	+2.2	—1.9	— .1	— .7	—1.3	+1.6
Kohala	+ .5	— .5	+ .4	— .1	+1.0	—1.4	+ .1	— .3	—1.0	+1.6
Union	+1.1	— .3	+ .9	— .3	+ .3	—1.4	+ .6	— .5	—1.2	+1.8
Hawi	+ .5	+ .2	+ .3	— .8	+ .6	— .8	+ .4	0	— .6	+ .6
Honokaa	+1.1	0	+ .2	— .3	0	—1.7	0	+ .7	— .6	— .7
Paauhau	+ .5	— .5	+ .3	+ .1	+ .4	—1.9	+ .7	0	— .6	+ .6
Hamakua	— .2	+ .2	+ .2	+ .4	+ .4	— .6	— .1	— .2	— .6	+ .2
Kaiwiki	0	— .3	+ .7	— .1	+ .5	— .8	+ .1	— .1	— .8	+ .9
Laupahoehoe	0	+ .3	+ .1	+ .1	+ .1	— .7	+ .3	+ .2	— .2	0
Hakalau	— .4	+ .2	+ .1	— .1	— .2	—1.0	+ .1	+ .4	— .6	+ .2
Honomu	— .3	+ .1	+ .2	0	0	— .9	+ .4	0	— .7	+ .1
Pepeekeo	— .3	+ .6	+ .1	— .2	+ .1	—1.2	+ .6	+ .1	— .6	0
Onomea	— .1	+ .2	+ .1	— .2	— .1	—1.1	0	+ .2	0	0
Hilo	—1.1	+ .5	— .2	+ .2	— .1	— .7	+ .1	+ .2	— .6	+ .1
Waiakea	0	+ .1	+ .5	— .5	+ .4	—1.6	+ .3	+ .3	+ .1	0
Olaa	— .4	+ .5	+ .5	— .2	+ .2	—1.0	+ .2	+ .1	— .2	+ .4
Hawn. Agri.	+ .5	— .1	+ .1	+ .4	— .4	— .7	+ .5	+ .2	— .2	+ .1
Hutchinson	— .3	— .1	+ .7	+ .4	— .4	—1.3	+1.7	+1.1	— .7	— .1
Kaeleku	— .3	+ .8	+ .5	+ .2	—1.1	—1.0	+ .7	+ .9	—1.0	+ .5
Maui Agri.	— .5	+ .3	+ .5	— .1	+ .2	— .3	— .1	+ .6	— .3	0
H. C. & S.	— .4	— .2	+ .2	+ .3	— .2	— .2	+ .3	+ .2	— .5	+ .2
Wailuku	— .2	— .2	+ .2	+ .4	+ .1	— .6	+ .1	— .2	— .8	+1.0
Olowalu	0	— .4	+ .2	— .2	+ .9	— .7	— .1	+ .1	+ .3	+ .3
Pioneer	— .2	— .2	+ .3	— .4	+ .4	— .5	+ .2	+ .2	— .4	+ .2
Kahuku	+ .6	+ .6	+ .9	— .2	0	—1.2	+ .7	+ .4	— .5	+ .2
Waialua	+ .2	— .2	+ .3	+ .2	0	— .5	+ .2	+ .6	— .6	+ .3
Ewa	+ .3	— .5	+ .3	+ .4	— .2	— .2	+ .2	+ .2	0	— .1
Waianae	— .5	— .1	+ .1	+ .2	—1.0	+ .1	+1.1	+ .2	— .1	— .2
Oahu	+ .1	— .2	+ .2	— .1	— .1	— .7	+ .4	+ .1	+ .1	— .1
Honolulu	+ .8	— .4	+ .7	— .1	+ .2	— .7	0	+ .5	+ .1	+ .3
Waimanalo	— .3	.....	.....	— .4	— .7	— .7	+ .8	+ .4	—1.2	+ .7
Kilauea	— .8	+1.7	+1.0	— .7	— .7	—1.0	— .9	— .7	+2.2	+ .2
Makee	— .4	+ .5	+ .2	0	— .6	—1.2	+ .2	+ .2	+ .4	— .1
Lihue	— .8	+ .4	+ .2	— .1	— .2	— .8	+ .1	+ .5	+ .4	— .5
Koloa	— .3	+ .4	+ .3	+ .1	0	— .8	— .6	+ .9	+ .3	— .2
McBryde	+ .9	+ .1	+ .7	— .1	— .2	— .4	+ .1	+ .4	— .1	— .6
Hawn. Sugar	+ .3	— .3	+ .3	0	— .2	— .2	— .1	+ .3	— .1	0
Waimea	.....	+ .1	— .4	+ .5	— .2	—1.3	+1.0	+ .2	— .1	+ .2
Kekaha	— .3	+ .1	+ .2	— .1	— .2	— .5	+ .1	+ .5	— .4	+ .2

The Use of Corn Oil for Thallium Wheat Torpedoes

By R. E. Doty

The thallium wheat torpedoes, as developed and reported by C. C. Barnum, appear to be an excellent means of poisoning rats. It is highly desirable, therefore, that these torpedoes be made more attractive.

With this in mind, Dr. A. J. Mangelsdorf suggested to the writer that certain vegetable oils be tried out as waterproofing materials for the torpedoes with the hope that the odors of the several oils might prove a special attraction to the rats.

Experiments were carried out from time to time at Kailua and the results tabulated.

Corn Oil, Sunflower Oil, Cocoanut Oil, Versus Paraffine Torpedoes, When Placed Together in Stations

Experiment 1-A:

This experiment was planned to determine the preference of rats for corn oil, sunflower oil, cocoanut oil, and paraffine when used to saturate the fibre spun wrapper to make the thallium wheat more attractive.

Three torpedoes of each kind were placed in groups or stations scattered at intervals of 15 to 25 feet along the edge of various fields of big cane at Kailua substation. Each station was staked and numbered for reference in tabulating the results. These stations were visited every day for three days and those torpedoes taken were replaced.

The results from 61 stations, representing a total of 420 torpedoes of each kind exposed for a period of 24 hours, are tabulated below:

	Corn Oil				Sunflower Oil			
	November			Total	November			Total
	13	14	15		13	14	15	
Total torpedoes put out	54	183	183	420	54	183	183	420
Number torpedoes taken	41	124	95	260	35	77	61	173
Per cent taken	75.9	67.8	52.0	**61.9**	64.8	42.1	33.3	**41.2**

	Cocoanut Oil				Paraffine Oil			
	November			Total	November			Total
	13	14	15		13	14	15	
Total torpedoes put out	54	183	183	420	54	183	183	420
Number torpedoes taken	37	72	55	164	4	14	26	44
Per cent taken	68.5	39.3	30.1	**39.0**	7.4	7.6	14.2	**10.5**

This test showed that corn oil was preferred, the rats having taken 61.9 per cent of the corn oil, 41.2 per cent of the sunflower oil, 39 per cent of the cocoanut oil, and only 10.5 per cent of the paraffine-dipped torpedoes. These results are presented graphically in Fig. 1.

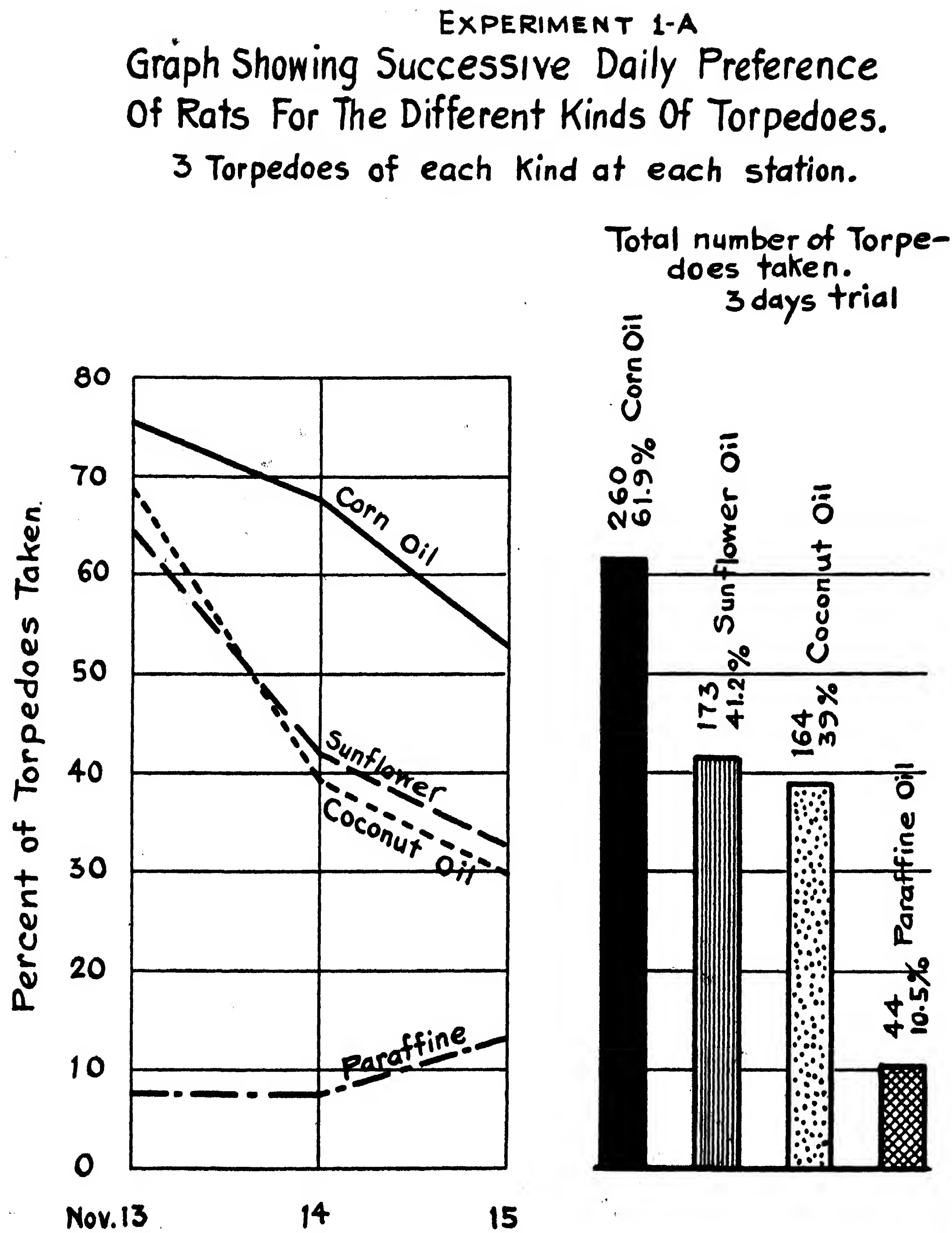


FIG. 1.

Experiment 1-B:

This test was undertaken as a duplicate of Experiment 1-A except that the number of each kind of torpedo was reduced to two.

The stations were visited daily for six days and the results tabulated.

This summary represents a total of 854 torpedoes of each kind exposed for at least 24 hours.

SUMMARY OF DATA COLLECTED IN FIELD L, KAILUA SUBSTATION

(2 torpedoes of each kind placed in each station each time they needed to be refilled)

CORN OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	34	60	79	44	67	80	364
Per cent taken	26.6	46.9	52.0	28.9	44.1	56.3	**42.6**

SUNFLOWER OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	17	49	58	36	42	35	237
Per cent taken	13.3	38.3	38.2	23.7	27.6	24.6	**27.8**

COCOANUT OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	20	35	36	25	18	16	150
Per cent taken	15.6	27.3	23.7	16.4	11.8	11.3	**17.6**

PARAFFINE OIL—CHECK

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	5	17	23	12	15	12	84
Per cent taken	3.9	13.3	15.1	7.9	9.8	8.5	**9.8**

Corn oil leads, with 42.6 per cent taken, followed by sunflower oil, with 27.8 per cent; cocoanut oil, with 17.6 per cent, and paraffine oil, with only 9.8 per cent.

The percentages in this test range somewhat lower than the former experiment, 1-A, due to the large number of torpedoes put out in a comparatively small area.

Fig. 2 presents in graphic form the successive daily preference of rats for the different kinds of torpedoes.

It is interesting to note that on the fourth day there was a decided drop in the consumption of the torpedoes. There was .31 inch of rain at that time. This would suggest that corn-oil-treated torpedoes be used in dry weather, otherwise their efficiency is greatly reduced and considerable material might be wasted.

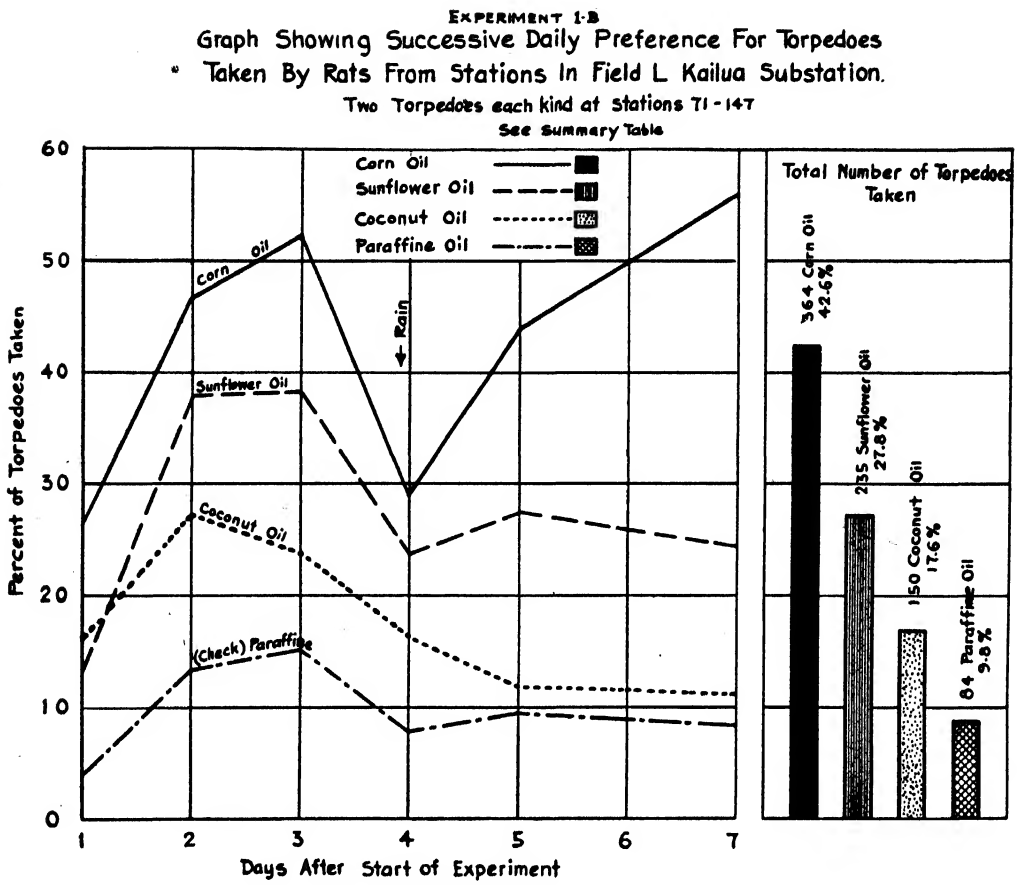


FIG. 2.

Experiment 1-C:

Another small test was conducted using only one torpedo of each kind in each station.

A total of 90 torpedoes of each kind were put out five different days.

The number taken of each kind follows:

	Number Taken	Per Cent
Corn oil	49	54.4
Sunflower oil	21	23.3
Cocoanut oil	20	22.2
Paraffine dipped	9	10.0

Corn oil continued to lead by a good margin, 54.4 per cent being taken as compared with the other treatments (sunflower oil, 23.3 per cent; cocoanut oil, 22.2 per cent, and paraffine 10.0 per cent). The total taken in all amounted to less than in the former experiments, probably due to a smaller rat population.

With only one torpedo of each kind available in each station, there was no tendency to open torpedoes and waste wheat, which was noted in the former experiments.

Dry Thallium Wheat in Dipped Wrapper Versus Corn Oil Wheat in Undipped Wrapper

Experiment 2-A:

A small test was conducted to determine the difference, if any, between torpedoes of dry thallium wheat dipped in corn oil, and torpedoes filled with corn-oil-saturated wheat, but not dipped. These treatments were checked with paraffine-dipped torpedoes.

This test was too small to draw conclusions, but it did show the trend. Out of a total of 120 torpedoes of each kind put out, 30 per cent of the dry wheat torpedoes dipped in corn oil were taken; 18.3 per cent of the torpedoes of corn oil in wheat with plain non-oil wrapper were taken, while only 13.3 per cent of the paraffine-dipped torpedoes were taken.

The detailed results follow:

No. of Torpedoes Put Out		No. of Torpedoes (Dry Wheat) Dipped in Corn Oil	Corn Oil in Wheat With Plain Non-oil Dipped Wrapper	Paraffine Dipped Plain Torpedoes
December 28........	72	19	11	9*
December 29........	48	17	11	7†
Total	120	36	22	16
Per cent taken.....		30	18.3	13.3

This table shows that it is of first importance that the paper wrapper be saturated with corn oil whether the wheat inside is saturated or not. If the wheat only is saturated and the torpedoes are not dipped, then sufficient oil must be put into the wheat to thoroughly soak the paper wrapper to make it really attractive. Subsequent experimentation indicated that this was not economical, as is discussed later in this paper. The wrappers of the torpedoes containing corn oil in the wheat naturally became somewhat oily from the oil in the wheat, but not saturated to any extent, as compared with those actually dipped in corn oil and allowed to drain on a screen.

Dry Thallium Wheat Versus Corn Oil Wheat Torpedoes When Both Have a Corn Oil-Dipped Wrapper

Experiment 2-B:

Another small test was put out to test the difference between dry thallium wheat and corn oil wheat when both kinds had been dipped in corn oil.

* All taken from three stations only.
† Same as above, only three different stations were attacked and torpedoes removed including the paraffine ones.

The results are tabulated below:

BOTH KINDS OF TORPEDOES DIPPED IN CORN OIL

	Dry Wheat Inside					Corn Oil Wheat Inside				
	March 11	12	13	14	Total	March 11	12	13	14	Total
Torpedoes put out......	154	154	77	77	462	154	154	77	77	462
Torpedoes taken	54	57	42	46	199	58	54	47	47	206
Per cent taken........	35.1	37.0	54.5	59.7	**43.1**	37.7	35.1	61.0	61.0	**44.6**

These results show that there was no preference between the dry wheat torpedo and the saturated wheat torpedo, provided they were both dipped in corn oil after making. This emphasizes the necessity of having the wrapper soaked with corn oil.

Corn Oil Versus Paraffine Torpedoes Placed Together at Manoa Substation

The study of the use of corn oil versus paraffine-dipped torpedoes was continued at Manoa substation under extremely wet conditions. It was found that with fewer torpedoes put out (one of each kind in one place) the tendency to open torpedoes and waste the wheat was entirely absent.

It was also noted with less bait available the percentage ratio of paraffine to corn oil increased. In the stations receiving two each, corn oil was 50 per cent taken, while paraffine was 14 per cent taken. Stations receiving only one of each kind gave a figure of 82 per cent for corn oil and 48 per cent for paraffine. Ants or slugs were found on some of the corn oil torpedoes remaining untouched on the second day. In some cases small holes were eaten in the paper. However, the number of torpedoes taken after three days would indicate that the rats did not pay much attention to either the ants or the slugs.

The tests discussed up to this point tend to show that rats, having found the torpedo stations, choose the various kinds of torpedoes in the amounts noted. In case there was not enough torpedoes to supply the demand, all would be taken and no preference could be determined. The ability of the rats to locate one or the other of the baits could not be detected by this group or station method.

It now remained to test the rat's ability to find isolated torpedoes of paraffine compared to corn oil when each are placed separately in or along the edge of big cane. This was tested out in Experiment 4, both at Kailua and Manoa substations.

Corn Oil Versus Paraffine Torpedoes When Spaced Singly

Experiment 4:

Single torpedoes of corn oil and paraffine were placed 10 to 15 feet apart, alternating, along the edge of big cane. The results obtained from this study at Kailua are tabulated below:

	Corn Oil	Paraffine
No. of torpedoes put out..........................	**470**	**470**
No. of torpedoes taken..............................	**344**	**125**
Per cent taken	**73.2**	**26.6**

This test is believed to be the best index of the usefulness of corn oil to increase the attractiveness of the thallium wheat.

The final percentages of this test are more favorable to corn oil than the previous tests, showing 73.2 per cent of the corn-oil-dipped torpedoes taken compared with 26.6 per cent of the paraffine torpedoes taken.

Corn Oil and Paraffine Mixture Versus Pure Paraffine When Torpedoes Are Spaced Singly

Having determined that corn oil was attractive to rats, it was desirable to attain greater waterproofing characteristics in the corn oil torpedo.

Mixtures of paraffine and corn oil were made up by adding varying amounts of corn oil to melted paraffine. Into these mixtures the fibre spun torpedoes were dipped by means of a wire basket in the same way as is done with pure paraffine.

Mixtures of corn oil and paraffine were softer and less waterproof than pure paraffine, depending on the amount of corn oil added. However, amounts up to 175 cc. of corn oil per pound of paraffine did not seriously injure it as a waterproofing material.

Experiment 5:

A test was put out at the Manoa substation, using torpedoes which had been dipped in a corn oil-paraffine mixture containing 175 cc. of corn oil per pound of paraffine. This was tested against pure paraffine-dipped torpedoes, both kinds being spaced 10 to 15 feet apart alternating with each other as was done in the previous experiment (No. 4).

The results of this test are summarized as follows:

SUMMARY OF TORPEDOES TAKEN BY RATS: CORN OIL AND PARAFFINE MIXTURE VS. PURE PARAFFINE

Corn Oil and Paraffine Mixture

	Jan. 27 1st Day	Jan. 28 2nd Day	Jan. 29 3rd Day	Totals
No. of torpedoes out	171	171	171*	513
No. of torpedoes taken	67	51	30	148
Per cent of torpedoes taken	41.6	29.8	17.5	**28.9**

Pure Paraffine

	Jan. 27 1st Day	Jan. 28 2nd Day	Jan. 29 3rd Day	Totals
No. of torpedoes out	171	171	171*	513
No. of torpedoes taken	23	22	16	61
Per cent of torpedoes taken	13.4	12.8	9.4	**11.9**

These data are presented graphically in Fig. 3.

It should be noted here that the rat population appeared to be comparatively

* **Rainfall on the previous night.**

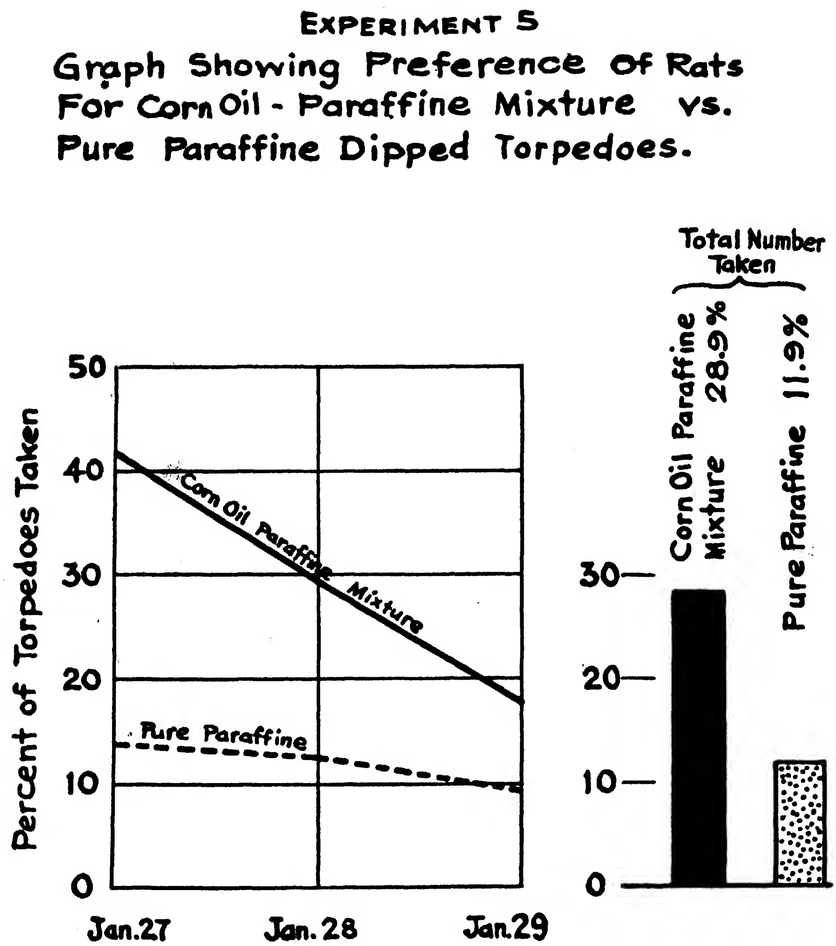


FIG. 3.

small, hence there were rather large areas in which no torpedoes of either kind were disturbed.

The only places where rats appeared numerous were along the edges of the field next to brush land. So the percentage of torpedoes taken was fairly low, but the ratio between the two kinds continues to favor the corn-oil-treated torpedoes.

Amounts of Material

The amounts of paraffine used will vary somewhat according to the temperature of the melted paraffine and the length of time the torpedoes are held in the hot wax.

In the trial dipping, 50 pounds of wheat torpedoes were treated with 5.2 pounds of corn oil-paraffine mixture, which gave the torpedoes a moderately heavy coating. This mixture was made up in the proportion of 175 cc. of corn oil to one pound of paraffine.

As this corn oil had a specific gravity of .91, 175 cc. are equivalent to 159.25 gms. This is 25.9 per cent by weight of the resultant mixture of corn oil and paraffine, which amounts to very slightly more than an even one part of corn oil

to three parts of wax. For practical purposes it will not be necessary to measure more accurately than this.

Modifications may be made as circumstances dictate, such as spraying the torpedoes, with or without dipping in paraffine, though these points were not studied in this endeavor.

Summary

The results of the tests performed to make thallium wheat torpedoes more attractive may be summarized as follows:

Rats showed a decided preference for corn oil over sunflower oil, cocoanut oil or paraffine as a material to saturate the paper torpedoes.

There was no waste of the wheat if only one or two torpedoes were put out in a place.

It was found that dry thallium wheat made into a torpedo and dipped was much better than a small amount of corn oil put into the wheat in an undipped wrapper. As long as the torpedo was dipped in corn oil, it made no difference whether the wheat contained corn oil or not.

The best test of the attractiveness of corn oil over paraffine was carried out by placing the two kinds of torpedoes singly and alternating, spaced 5 to 15 feet apart in or along a cane field. Seventy-three per cent of the corn oil torpedoes were taken, while only 26.6 per cent of the paraffine torpedoes disappeared in the same period.

A mixture of corn oil and paraffine (one part of corn oil to three parts of paraffine by weight) was applied successfully to a trial lot of torpedoes. This treatment offers the best practical method of combining corn oil with paraffine for waterproofing thallium wheat torpedoes.

Further Studies on the Distribution of Soil Moisture Under the Border Method of Irrigation

By H. R. Shaw

A recent issue of *The Hawaiian Planters' Record** reported a series of studies on the penetration and distribution of soil moisture on three distinct plantation soil types and under three methods of irrigation. The investigation indicated that under the Hawaiian contour method at the Waipio substation and under the long line method of irrigation at Waimanalo, the lateral penetration of moisture to each side of the furrow seldom exceeded 24 inches regardless of the quantity of irrigation water applied. The vertical penetration was roughly proportional to the quantity of water applied at the surface. Soil moisture analyses, based on the "relative wetness" or ratio between total moisture content and the moisture equivalent, demonstrated that at all points within the zone of wetted soil caused by the irrigation, the soil was at the same relative moisture content. The soil immediately outside the visible wetted zone was at a relatively low moisture content, and it was apparent that such soil had received no moisture from the current irrigation. Moreover, the investigation demonstrated that there is no appreciable movement of soil moisture after 48 hours from the time of irrigation, and that the effectiveness of capillary attraction in the movement of water from moist to dry soil is negligible. The evidence gained from the investigation led to the conclusion that each increment of soil must be wetted to its maximum field capacity, the greatest amount of water that can be held by the soil against the force of gravity, before other increments of soil can be wetted.

Similar studies were reported in the previous paper on the distribution of moisture under the border method of irrigation in a field at the Ewa Plantation Company. It was impossible at that time to conduct the investigation in a plowed field immediately after the first irrigation as had been the case with the studies on contour and on long line irrigation. The studies were made in a field of cane 5 to 6 feet high which had received 15 irrigations prior to the period of the investigation. It was found that the entire soil mass vertically below the bed of the border was at its maximum field capacity to an indefinite depth exceeding 10 feet. Consequently it was impossible to determine the exact extent of moisture penetration caused by the current irrigation. It was concluded that "quantities of water applied in early irrigations and not used by the feeding roots of the plant pass to the lower soil horizon until each successive increment of soil is filled to its maximum field capacity. As more of such excessive applications of water are made, the water probably percolates through the soil until it reaches the subterranean water table. In view of the preceding evidence on the failure of capillary attraction to convey water for any distance through the soil, it appears improbable

* "The Distribution of Soil Moisture After Irrigation," Shaw, H. R., *Hawaiian Planters' Record,* Vol. XXXVI, January, 1932.

that any water penetrating below the normal root range is ever recovered by the plant."

An opportunity arose in January, 1932, to study at the Ewa Plantation the manner and extent of soil moisture distribution under the border method of irrigation in a field previously occupied by a labor camp and gardens, and which was being plowed and put under cultivation to sugar cane for the first time. The soil was a finely divided, grayish brown loam free from rocks and apparently from soil irregularities. The greater portion of the field was on a gentle and uniform natural gradient of approximately 1.5 per cent. The borders were 20 feet wide from levee to levee, and were 1050 feet in length. Small furrows, 4 to 6 inches deep, were made in parallel 5 feet apart in the border in order that certain economies in water application and in the subsequent control of weed growth might be effected. After the cane has reached an age of 4 to 5 months, it is planned to fill and level these small furrows, subsequent irrigations being made by the more usual method of flooding the entire border. This adaptation, which has been used successfully on the plantation of the Hawaiian Commercial and Sugar Company in 1931, is termed the long line-border combination method, as the distribution of water at the start of the crop is typical of the long line or furrow method.

Seven adjoining borders in the center of the field were chosen for the investigation. Four borders were given a normal first irrigation by plantation labor. Although it was not possible to measure the quantity of water applied to each border, the average application was estimated to be approximately 2.0 acre inches per acre. At points in each border 625, 725 and 900 feet from the level ditch, the border bed was levelled from side to side for a distance of 10 to 15 feet so that the application of water was typical of the true border method of irrigation. The three alternate borders remained unirrigated so that the lateral penetration of moisture might be determined.

On the day following the irrigation, a narrow trench was dug athwart each irrigated border at points 625, 725 and 900 feet from the level ditch. The line of demarcation between moist soil caused by the current irrigation and the relatively dry soil was clearly visible on the face of the trench. The perimeter of this wetted zone was marked by pins set in the trench face at intervals of about three inches. The coordinates of each pin were recorded, and the zone mapped.

Soil moisture samples were taken at various spots within and without the wetted area. In each position two samples of approximately 150 grams each were taken. One sample was weighed within 12 hours of the time of sampling, dried at 110° C. in an electric oven for 48 hours, and the total moisture content on an oven dry basis determined. The other sample was divided into two portions and the moisture equivalent of the soil determined in duplicate. The moisture equivalent of Hawaiian soils has been found to bear a remarkably constant relationship to the maximum field capacity of the same soil. This relationship may be expressed as: maximum field capacity = moisture equivalent × 1.1.

The basis used in the comparison of ~~soil~~ moisture data in the studies described here is the "relative wetness" or total moisture content × 100 ÷ moisture equivalent. If the "relative wetness" of a set of samples ranges in value from 100 to 110, the soil may be considered to be at its maximum field capacity. If the value

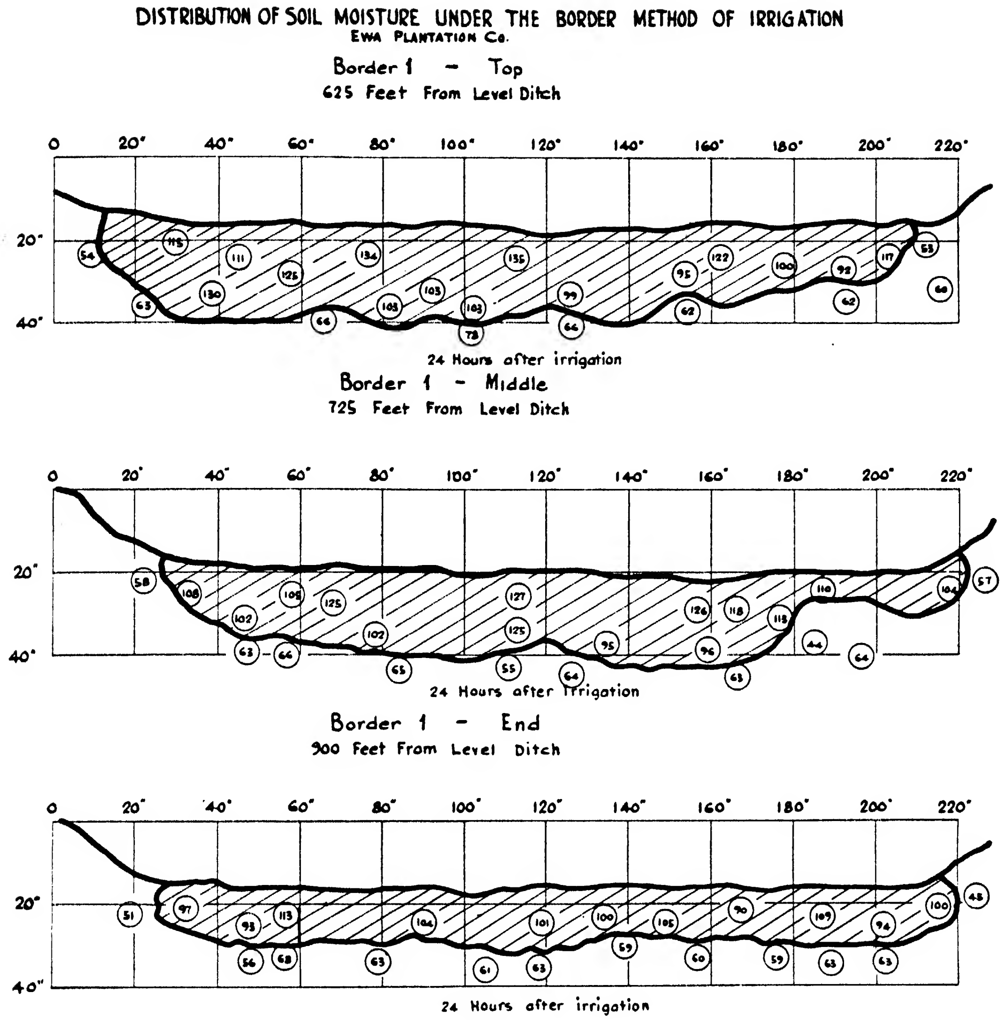


FIG. 1.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

is considerably above 110, it is assumed that the soil and water are not yet in equilibrium and that further movement due to gravity may take place. If the value is considerably lower than 100, it appears safe to assume that the soil is far below its maximum field capacity, and probably that no moisture has been added to the soil by the current irrigation.

Fig. 1 shows the distribution of soil moisture 24 hours after the first irrigation by the border method to land of uniform and gradual slope. At a point 625 feet from the level ditch the vertical penetration of moisture averages 20 inches below the border bed. The lateral penetration is negligible and extends but a few inches beyond the extremes of the surface application of water. At 725 feet from the level ditch the vertical penetration does not exceed 20 inches and is considerably less at each side of the border where the surface application was apparently less than at the center. At 900 feet from the level ditch or 150 feet from the end of the border, the vertical penetration is not over 12 to 14 inches or about half the

penetration at the other points in the border. Inspection of the soil moisture data, as expressed by the "relative wetness" ratio, reveals that at points 625 and 725 feet from the level ditch, the soil near the surface is at a moisture content somewhat greater than its maximum field capacity and that a slightly greater penetration due to gravity may be expected after 24 hours. There is no evidence, however, of a gradation in moisture distribution at the lower limits of the wetted zone. The "relative wetness" of samples taken just within the visible perimeter of the wetted area indicates that the soil is at its maximum field capacity while the ratio of samples taken but a few inches outside the wetted area ranges from 50 to 65 per cent of the soil's possible capacity, indicating a sharp transition between moist and dry soil. The soil at all points within the wetted zone 900 feet from the level ditch is at its maximum field capacity while the soil immediately outside the perimeter is at a relatively low moisture content.

Fig. 2 demonstrates the effect of slight changes in the slope of the surface of the border on the resulting penetration of moisture. At 625 feet from the level ditch the shape and extent of the wetted area resemble Fig. 1 at the same point.

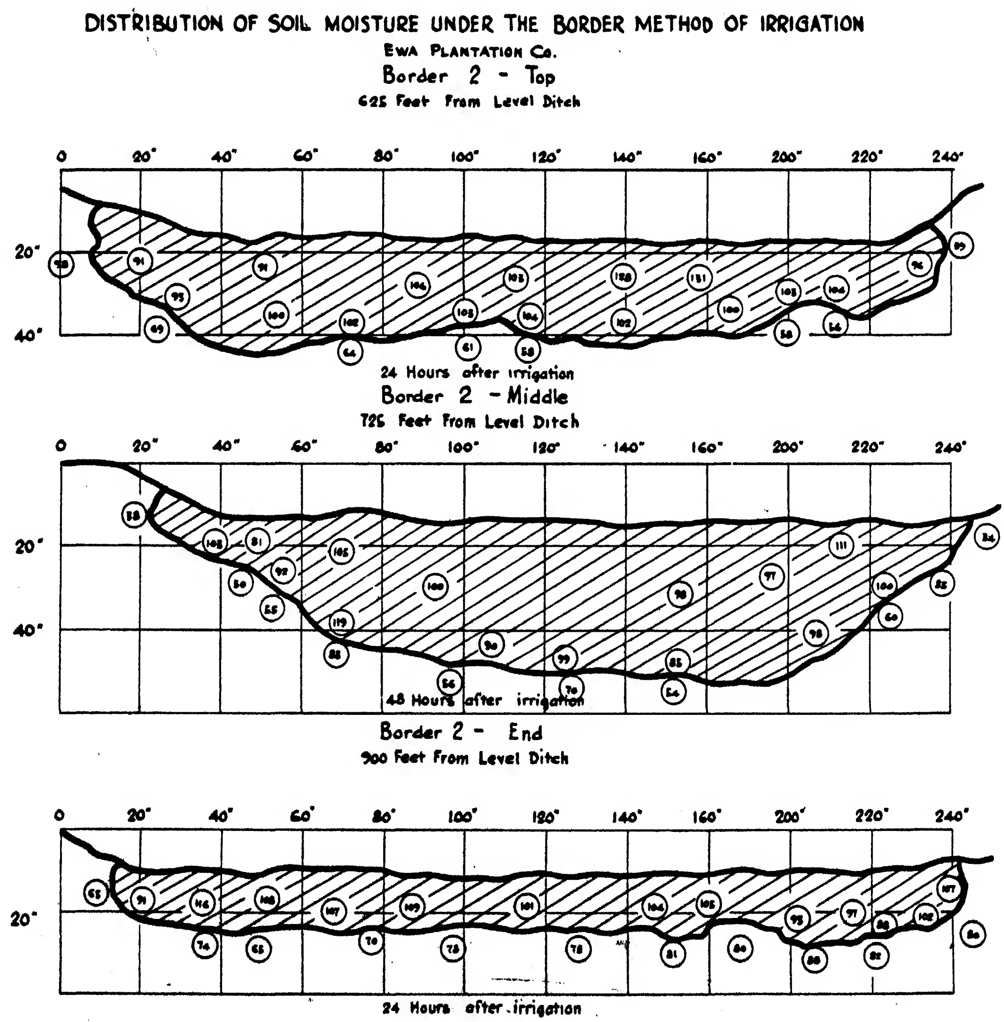


FIG. 2.
Distribution of soil moisture under the Border Method of irrigation.

With two exceptions, the "relative wetness" ratio indicates that the soil is at its maximum field capacity at all points within the wetted zone, and consequently that there will be no further downward movement of moisture. A slight swale or depression in the border 725 feet from the level ditch resulted in an accumulation of water on the surface and a relatively deep vertical penetration. The penetration at the center of the border ranges from 36 to 40 inches, with an abrupt upward gradation at the sides of the border. The penetration of moisture 900 feet from the level ditch again is comparatively slight and seldom exceeds 14 inches. The relative moisture content of the dry soil immediately below the wetted zone is somewhat higher than that in other cases, due, probably, to local surface conditions occurring before the field was plowed which prevented the exhaustion of residual soil moisture to as great an extent as that in other parts of the field. Such a condition might be caused by a road, barren area, or group of buildings which would allow a penetration of moisture from rainfall but would prevent an exhaustion of soil moisture by plant growth.

The penetration of moisture in Border 3 at a point 625 feet from the level ditch resembles that of other cases shown except that there appears to be a slightly greater lateral penetration of moisture at the left-hand edge of the border caused apparently by a slight depression and consequent accumulation of surface water at that point. The vertical penetration of moisture 900 feet from the level ditch is even less than in other cases noted, the penetration averaging less than 8 inches.

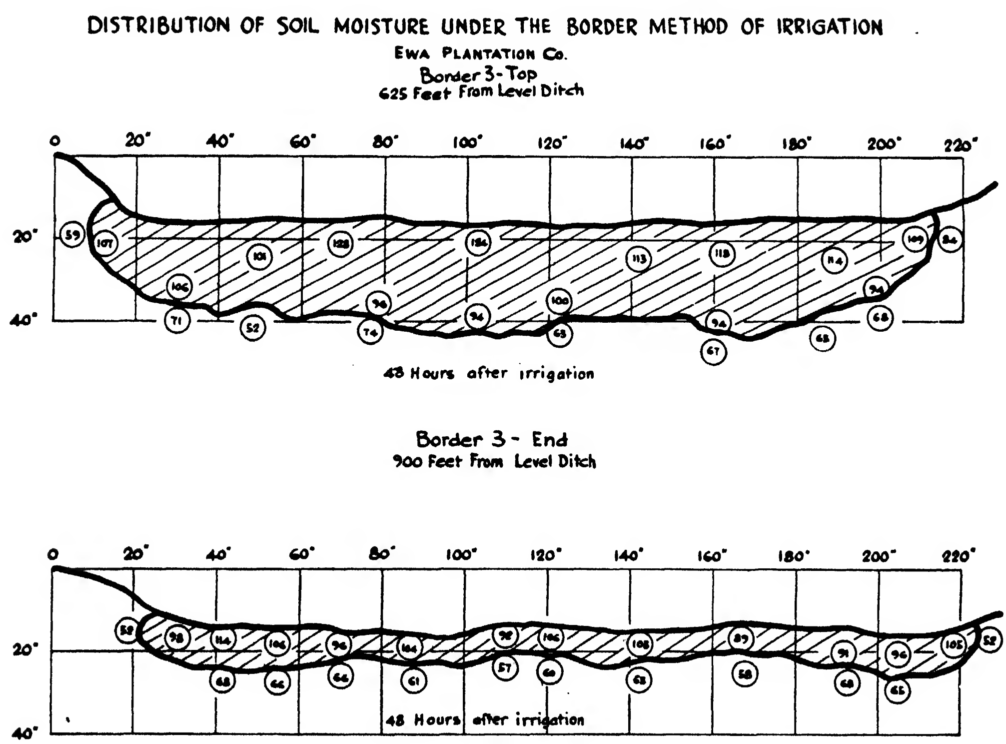


FIG. 3.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

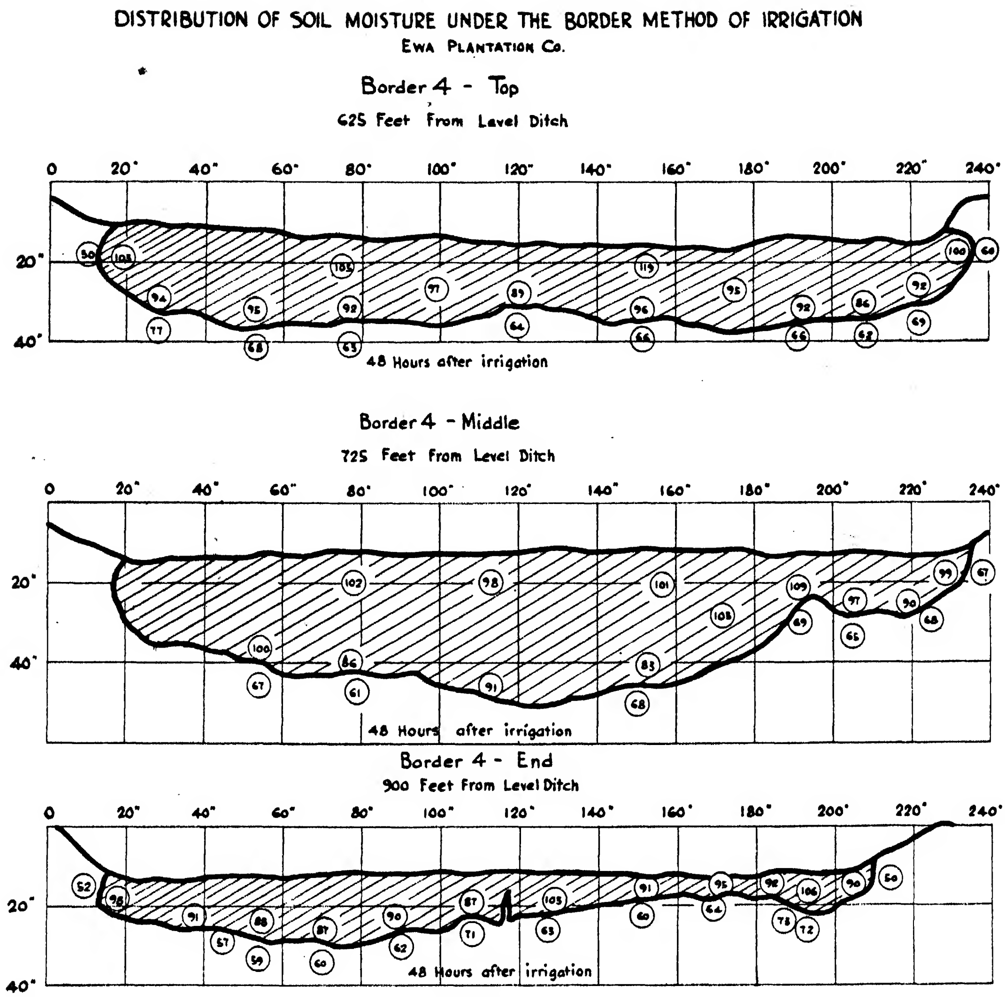


FIG. 4.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

The trench constructed 725 feet from the level ditch in this border was abandoned because of a localized condition resulting in an accumulation of residual soil moisture which made it difficult to locate the limits of the wetted area.

Fig. 4 is another example of the effect of a changed surface gradient on the resulting penetration of moisture. The penetration at 625 feet from the level ditch averages 21 inches, but that at 725 feet from the ditch is considerably greater, ranging from 36 to 40 inches in the center and averaging 26 inches. The greater penetration in the second case is probably due to a change in surface gradient causing a check or slight accumulation of irrigation water at this point. The penetration of moisture 900 feet from the level ditch is again relatively scant except at the left half of the border where a change in level from side to side apparently resulted in a slight accumulation of surface water.

In order to gain an idea of the nature of soil moisture distribution under the long line-border combination method by which irrigation water to the seed and young cane is applied in small, shallow furrows 5 feet apart rather than by flood-

ing the entire border, trenches were dug athwart the border at points 250 and 475 feet from the level ditch in Border 1. The wetted zones, which were clearly visible on the trench face, were marked and plotted in the manner described previously although no soil moisture samples were taken. It may be seen from Fig. 5 that the distribution of moisture by this method is typical of that under the long line method of irrigation described in a previous report. The wetted zones are roughly elliptical in shape with the major axis in a horizontal direction. The vertical penetration 250 feet from the level ditch was slightly over 20 inches below the base of the furrow. The lateral penetration was slight, and there was no

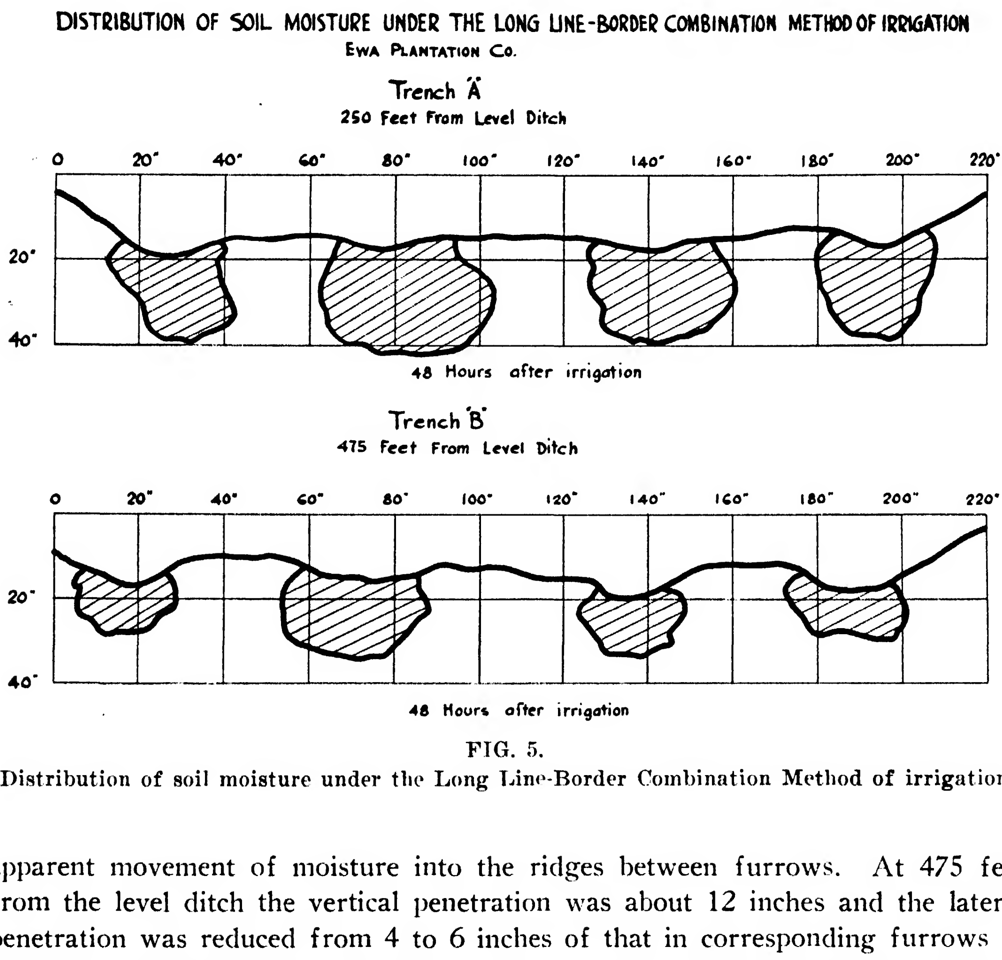


FIG. 5.
Distribution of soil moisture under the Long Line-Border Combination Method of irrigation.

apparent movement of moisture into the ridges between furrows. At 475 feet from the level ditch the vertical penetration was about 12 inches and the lateral penetration was reduced from 4 to 6 inches of that in corresponding furrows at 250 feet. In other words, a variation in the amount of surface application affected greatly the resulting vertical penetration, but affected only slightly the resulting lateral penetration.

In Table I is given the true area of the wetted zone, and the average vertical penetration of moisture in each of the cases studied. The area of the wetted zone was determined by tracing the mapped outline of each wetted zone with a planimeter and making the proper scale conversion. The "effective border width" is the width in inches of that portion of the border to which irrigation water was actually applied rather than the width from levee to levee. The average depth of

penetration was determined by dividing the area in square inches by the effective border width.

TABLE I

AREAS OF WETTED ZONES RESULTING FROM FIRST IRRIGATION APPLICATION

Border	Area of Wetted Zone Sq. Ins.	Sq. Ft.	Effective Width of Border	Average Depth of Moisture Penetration
1—Top	3903.768	27.102	196 inches	20 inches
1—Middle	3213.708	22.317	192 "	17 "
1—End	2563.080	17.799	192 "	13 "
2—Top	4626.688	32.130	206 "	22 "
2—Middle	5369.324	37.287	200 "	27 "
2—End	2983.688	20.720	208 "	14 "
3—Top	4455.816	30.943	200 "	22 "
3—End	1570.708	10.908	198 "	8 "
4—Top	4436.100	30.806	212 "	21 "
4—Middle	5586.200	38.793	214 "	26 "
4—End	2195.048	15.243	194 "	11 "

The data in Table I demonstrate that within the relatively short distance of 275 feet there may be a considerable difference in the area of soil wetted by an irrigation application, and in the vertical distance penetrated by the water. In the cases reported here, the average depth of penetration at a point 900 feet from the level ditch is about one-half of that 275 feet nearer the ditch. The area wetted by the irrigation water 900 feet from the level ditch is from one-third to two-thirds of that nearer the ditch. The probable causes and results of this variation will be discussed in greater detail later in the paper.

That a considerable fluctuation in the quantity of irrigation water applied at various points in the border if the land surface is not level from side to side and uniform in slope, is evident from the variations noted in the size of the wetted areas resulting from the irrigation. An approximation of the quantity of water applied to the surface of a homogeneous soil when certain other factors are known may be gained from the equation:

$$D = P \times V \times d$$

Where $D =$ the depth of the surface application in acres inches per acre; $P =$ the range in soil moisture under consideration; $V =$ the volume weight or apparent specific gravity of the soil; and $d =$ the depth of moisture penetration in inches.

Three of the factors in this equation may be estimated closely for the soil under consideration. 'P', the range in soil moisture percentage involved, may be determined by subtracting the average per cent moisture of the dry soil outside the wetted zone from the average per cent moisture of the soil within the wetted zone. 'V', or the volume weight of the soil, has been determined by the writer for a large number of Hawaiian soils,* some of which were in the close vicinity of the field under consideration. An estimated value of 1.1 for the volume weight of

* "Variation in the Volume Weight of Hawaiian Soils," H. R. Shaw, Progress Report, Project A-4, Expt. Sta. H. S. P. A.

the soil may be considered sufficiently accurate. The value of 'd', or the average depth of moisture penetration is given in the last column of Table I.

With three of the factors of the equation known, an approximation of the quantity of irrigation water applied at various points in the border is given in Table II.

TABLE II

VARIATION IN THE QUANTITY OF IRRIGATION WATER APPLIED AT VARIOUS POINTS IN A BORDER, AS OBTAINED FROM THE EQUATION: $D = P \times V \times d$

Border	Soil Moisture Percentage Before Irrigation	After Irrigation	'P' or Range in Soil Moisture	'V' Estimated Volume Weight	'd' Depth of Moisture Penetration	'D' Probable Surface Application of Irrigation Water
1—Top	16.7	29.3	.126	1.1	20 inches	2.77 acre inches
1—Middle	16.5	29.2	.127	1.1	17 "	2.37 per acre
1—End	16.2	29.1	.129	1.1	13 "	1.84 "
2—Top	15.5	28.2	.127	1.1	22 "	3.07 "
2—Middle	15.4	26.7	.113	1.1	27 "	3.36 "
2—End	21.1	29.6	.085	1.1	14 "	1.31 "
3—Top	16.3	27.2	.109	1.1	22 "	2.64 "
3—End	16.2	26.2	.100	1.1	8 "	0.88 "
4—Top	16.5	25.9	.094	1.1	21 "	2.17 "
4—Middle	18.3	26.1	.078	1.1	26 "	2.23 "
4—End	16.1	24.8	.087	1.1	11 "	1.05 "

Discussion

In general, the evidence of this investigation on the distribution of soil moisture under the border method of irrigation indicates that the penetration of soil moisture is more than adequate for the germination of seed and the growth of the cane plant. It would appear that, with the possible exception of a relatively short distance near the end of the border, the zone of soil moisture penetration is far greater than is necessary for the actual supply of water to the plant. As successive applications of irrigation water in excess of the needs of the plant are made, it seems probable that the lower limit of the moist zone will move downward by gravity until the entire soil mass for an indefinite distance below the bed of the border will be at its maximum field capacity. It appears, therefore, that precautions must be taken with the border method of irrigation, even more than with other methods, to prevent the drainage of irrigation water and soluble nutrients below the potential root zone of the plant.

The use of the long line-border combination method seems to be effective in reducing excessive losses of irrigation water during the early portion of the crop periods. The wetted zone below each furrow, as shown in Fig. 5, is adequate for the germination of seed and the early growth of the cane. The fact that there appears to be no lateral movement of moisture into the ridges between furrows should also prove effective in the curtailment of weed growth between cane rows, previously a serious objection in many quarters to the border method of irrigation. However, in soils of the type described here and in regions with little rain-

fall, it would appear desirable if not imperative to level the furrows and revert to the usual border method as soon as the cane develops considerable foliage and an extensive root system. It seems certain that in localities dependent for long periods solely on irrigation, root development in the dry ridges between furrows will be handicapped, if not completely curtailed. The complete distribution of water across the entire border would surely tend toward a greater lateral root development and possibly a greater availability of soluble nutrients in the soil.

The necessity for careful preparation and leveling if a uniform distribution of moisture is to be gained seems apparent from the results of the investigation. A change in level from side to side may affect seriously the depth of penetration of soil moisture. Changes in gradient down the length of the border may also be reflected in excessive penetration of moisture in depressions and an inadequate zone of moist soil on the high spots.

The reasons for the relatively scant penetration of moisture near the end of each border deserve more than passing comment. The previous report on the distribution of soil moisture under the border method after the fifteenth irrigation mentioned this effect as follows: "With the technique now used in border irrigation, the water is turned off at the headgate when the advancing sheet of water is yet some distance from the end of the border. It seems not unlikely that there may be a short distance, between the position of the advancing water at the time the supply is stopped and the point at which water backs up from the end of the border, at which the penetration of moisture might be inadequate, and a modification of the colloidal properties of the soil such as to cause a hardpan formation might occur. Such a zone of inadequate penetration near the end of the border is often reflected in reduced cane growth under the border method of irrigation."

The assumption made in the preceding paragraphs seems to be verified by the results of the present investigation. The inadequacy of moisture penetration 150 feet from the end of the border in each case is certainly due to a limitation of supply rather than to an increased gradient or to the physical nature of the soil. The limited area of moist soil at this point seems likely to jeopardize the opportunity for optimum plant growth. Experience with the border method of irrigation indicates that the inadequate penetration of moisture is caused, not by the length of the border, but by stopping the stream of water at the headgate before the advancing sheet reaches the end of the border. It would appear, however, that the shorter the border the greater the control of the water. Hence it seems probable that with borders from 300 to 500 feet long the stream at the headgate might be controlled with much greater precision than is the case with borders 1000 to 1200 feet long. Another suggestion for the elimination of the zone of inadequate moisture penetration near the end of the border has been the construction of small earth or trash dams which will check the flow of water and allow a greater penetration of moisture. A third possibility is the construction of small drainage ditches from the end of the border to the next lower level ditch. Thus, the stream would not be turned off at the headgate until the advancing sheet of water had completely reached the end of the border. Excess water would then be drained from the end of the border to the level ditch below.

Summary

1. This paper reports a study on the distribution of soil moisture under the border method of irrigation after the first application of water to a newly plowed field on the Ewa Plantation.

2. Trenches were dug athwart each of four borders at points 625, 725 and 900 feet from the level ditch. The zone of wetted soil, visible on the face of the trench, was mapped and studied.

3. The vertical penetration of soil moisture after the first irrigation varied from a minimum of 6 inches to a maximum of 40 inches. The degree of moisture penetration seemed greatly affected by the surface gradient of the land. Lateral penetration was negligible.

4. The area of wetted soil caused by the irrigation application appeared more than adequate for the germination and early growth of cane, and it appeared probable that losses of water and soluble nutrients might occur, especially during the first few months of the crop.

5. The long line-border combination method, by which irrigation water is applied to the seed and young cane in small furrows rather than by flooding, appears to be effective in the conservation of water and the curtailment of weed growth between cane rows. The advisability of reverting to the true border method of irrigation as soon as root and foliage development of the plant has progressed, especially in localities having fine-grained soil and low rainfall, is suggested.

6. The reasons and possible corrective measures for a relatively inadequate penetration of moisture noted near the end of the border are discussed.

7. Soil moisture data indicate that, in general, the soil at all points within the visible wetted zone is at a relatively uniform moisture content. There is a sharp transition between moist and dry soil, the region immediately outside the wetted zone apparently not having received any moisture from the current irrigation. There is no evidence of a movement of soil moisture by capillarity or other means after 48 hours from the time of irrigation, and any movement after 24 hours from irrigation was almost imperceptible.

Acknowledgments

The writer is indebted to George F. Renton, manager, to Harold Dyson, head irrigation overseer, and to J. B. Menardi, Jr., and Burt Bacon, agriculturists, of the Ewa Plantation Company, for the opportunity of conducting this study, and for their hearty cooperation in the prosecution of the work.

Some Observations on Forest Insects at the Nauhi Nursery and Vicinity on Hawaii

By O. H. Swezey

Through the courtesy of the department of forestry, Dr. F. X. Williams and the writer had the opportunity of spending a week the latter part of September and beginning of October, 1931, at the forest nursery on Nauhi Gulch, at an elevation of 5250 feet. This is at the upper edge of the Hilo Forest Reserve, and in the land of Honohina, about 12 miles up from the coast. It is in a region of this great forest belt on windward Hawaii which has never been explored entomologically. During the few days there, we studied the insect faunas of the chief trees making up the jungle in the forest reserve, and the remaining trees in the ranch land which occupies a wide belt above the forest. We also went up the side of Mauna Kea above the forest line to an elevation of 8500 feet.

The koa is a prominent tree of the region, and, as evidenced by standing dead trunks and rotten logs, formerly made up a considerable part of the forest that previously covered the land, which has been occupied by the ranch for a long period of time. There are some remaining live trees on the ranch, particularly in and along gulches. The most prevalent tree in the forest reserve is the lehua. It also extends somewhat up into the ranch area. The mamani makes up a considerable belt of open forest at an elevation of 7000 to 8500 feet, with scattering trees at lower elevations. The naio has scattered stands in the ranch area. Kolea is found sparsely in the forest reserve and also somewhat higher up. The same applies to the olapa. The mamake is not common and Broussaisia is more in evidence in the forest reserve. A species of Coprosma is quite common in the jungle of the forest reserve and is also found in the gulches at higher elevations.

Of the undergrowth making up the jungle of the forest reserve there are many pulu ferns; also thickets of akala, and clumps of a tall species of ohelo are common; puakeawe is also abundant in places.

Certain trees which are usually components of the endemic forests were not observed in the region, namely: Straussia, Bobea, Pelea, Elaeocarpus, Antidesma, Perrotettia, Maba.

Insects Affecting the Koa (*Acacia koa*)

Two species of leafhopper (*Ilburnia koae* and *Ilburnia pseudorubescens*) were found on the new foliage of young trees and on new sprouts on the trunks of old trees. They were the most numerous on young trees, but not numerous enough for significant injury.

An occasional caterpillar of the koa moth (*Scotorythra paludicola*) was found feeding on new foliage, but not numerous enough to be harmful; an occasional larva of the small butterfly, *Lycaena blackburni*, also was found feeding on new foliage.

The growing seeds in pods are badly eaten by larvae of the koa seed moth (*Cryptophlebia illepida* var. *fulva*). Counts were made in 87 pods, and of the possible 644 seeds, only 201 or 31 per cent had matured, while 395 or 61 per cent had been destroyed by larvae of the moth. A few larvae were still feeding on green seeds. From these, four moths matured October 21 to 30.

In dead branches of living trees were found larvae and pupae of one species of native koa borer, *Plagithmysus varians*. A few of the adult beetles were found also in the pupal cells in the wood where they had matured, and had not yet issued. A number of pieces of dead branches containing larvae were taken to the laboratory, and from these 14 beetles matured and issued October 31 to November 16. The living healthy trees were not attacked by this insect, but the larvae were always to be found in the dying branches resulting from crowded growth or lack of nourishment. They were also found in places where trunks of trees had been injured, and in fallen trees. In the latter they were particularly numerous, if the tree had been down a few months. The adult beetles are attracted to fallen trees, broken branches, or dying branches of trees, and place their eggs in cracks or crevices of the bark. On hatching, the larvae feed in the inner fermenting bark, which is their preferred food; on increasing in size they feed also on the outer layer of the wood, forming grooves, where they are feeding beneath the bark. If the bark becomes too dry, they burrow into and feed on the wood exclusively, and when they have reached their full growth, if they have not already burrowed into the wood, they burrow in sufficiently to form a cell for pupation, in which they eventually transform to the adult beetle. The adult beetles issue from round holes which they gnaw through the bark. Sometimes the holes are very numerous in old, dead standing trunks, and this leads to the impression that the trees have been killed by these borers. A study of the habits of the insect demonstrates, however, that it is only a secondary factor, the primary factor being some unfavorable conditions of environment, the insect attack beginning when the tree or its branches are in a dying condition.

Another contributor to the number of holes in standing dead trunks is an oval black beetle (*Oodemas corticis*), the larvae of which feed only in dead and rotten wood. We found many of the beetles as well as the larvae in rotten logs on the ground and in standing dead koa trunks. In the latter were the numerous round holes from which the beetles had issued after becoming mature in their pupal cells. These pupal cells were readily distinguishable from those of the previously discussed borer, being shorter as this beetle is shorter in all stages than the preceding, though the diameter of the hole by which it issues from the tree is about the same. Another distinction is that the borer, *Plagithmysus varians,* issues while the bark is still on; whereas the adults of *Oodemas corticis* only issue at later stages in the decay of the tree.

Rotten koa logs on the ground were found to have quite a miscellaneous population of insects. Among those feeding on the rotten wood besides the Oodemas above, were three species of weevils (*Dryophthorus insignis, D. declivis.* and apparently a new species of Dryophthorus); two kinds of moth caterpillars belonging to the genera Semnoprepia and Thyrocopa, of which none was reared, which would be necessary to determine the species. There were also the wireworm-like

larvae of beetles of the genus Dromaeolus, which probably feed on juices from the wet, rotten wood. No adults were found, and no larvae were reared to maturity, but wing-covers were found belonging to the species *perkinsi.* Real wireworms were also found in the rotten wood where they were probably predators on some of the other insects. These wireworms were larvae of a native species of click-beetles. A few wing-covers and other remains of the beetles were found, which served to identify the species as *Eopenthes konae.* Other predators were: adult carabid beetles of two or three species, mostly a small species which appears to be *Mecyclothorax konanus;* larvae and adults of two staphylinid beetles, *Philonthus scybalarius* and *P. turbidus.* The larva of the latter was found to have an interesting parasite which was a new discovery in the genus Proctotrypes.

Insects of Ohia Lehua (*Metrosideros polymorpha*)

Insects specially feeding on the lehua were not particularly abundant. An occasional caterpillar was found on the foliage which was probably *Scotorythra rara.* None was reared, however. The moths came to light quite numerously. In moss and rotten logs near base of lehua trees a few large pupae were found of the large moth *Scotorythra hyparcha.* It is supposed that the caterpillars of this moth feed on the foliage of lehua, but none was found, however. They must have been fairly common a short time previously, for the moths came to light at night in large numbers.

A leafhopper (*Leialoha lehua hawaiiensis*) was found on the young twigs, but not common. One or more species of leaf-bugs were found. None of these insects was numerous enough to injure the trees. The little psyllids which produce galls on lehua leaves nearly everywhere, were scarce, only occasionally found. A few of a species of Proterhinus bark beetle were beaten from dead twigs. In rotten logs, the same new species of Dryophthorus was found that occurred in koa logs.

Insects of the Mamani (*Sophora chrysophylla*)

A small green mirid bug was very numerous on the foliage of the mamani tree. They did not seem to affect the tree badly, however. Another species of smaller size was also present in some places in less numbers. A few caterpillars were found of some species of Scotorythra, but they failed to mature so that the species was not determined. In dying and dead trees were numerous larvae of the species of borer beetle which is specially attached to mamani: *Plagithmysus blackburni.* Eleven of the adult beetles were collected resting on the branches of one dead tree. These beetles fly up so suddenly when disturbed, that one has to be very quick or he will miss capturing them. The larvae of this beetle work similarly to the species described above on koa trees. The larvae feed in the inner bark of dying trees, or dying branches; then burrow into the wood to form the cell or chamber for pupation and maturing to adult beetles. In the numerous dead or partly dead trees in the region where the mamani predominates, the borer holes are numerous and conspicuous where the bark is off, and this easily leads to the misconception that the trees have been killed by the borers, just as in the case of koa trees. The study of this insect has shown that it is the sickly or dying trees

which are attacked. The mamani tree is adapted to living under very unfavorable conditions such as dry, barren regions, and has continued to exist as a considerable forest at an elevation from about 6500 to 8000 feet in spite of the fact that it has been pastured for a long time. Those trees which succumb from time to time are enough to furnish feeding grounds for this beetle in considerable numbers. A few of the mamani seeds are eaten in the pods by larvae of the moth *Adenoneura plicatum,* which is related to the moth that is so destructive to koa seeds.

Insects of the Naio (*Myoporum sandwicense*)

There were not many of this tree left in the region, but in places were groups of dead trees, and a few that were yet alive. The only insect of importance found associated with this tree was the borer *Plagithmysus perkinsi,* one of the larger species of this group of borers. The larvae were found abundant in dying trees. They were found to be feeding in the healthy bark and wood, and no doubt are partially responsible for the death of the trees.

Insects of Pilo (*Coprosma* sp.)

This medium sized tree was common in the forest reserve and also occurred in the sides of gulches up to about 7000 feet elevation. A small mirid bug was numerous on the foliage, and a few of a species of jassid were collected. None of these was particularly detrimental to the tree. In and beneath the bark of a dead tree at Keanakolu were found several kinds of small beetles: *Proterhinus vulcanus, Mirosternus* sp., *Cis porcatus, Cis cognatissimus* and *Cis signatus.* None of these has a harmful habit.

Insects of Kolea (*Suttonia lessertiana*)

This tree occurred rather sparsely in general. One small grove was noted at about 6000 feet elevation in the ranch land. The caterpillars of a tortricid moth (*Eulia* sp.) were often found feeding on the leaves of the terminal bud, and also boring in the twigs, thus killing the ends of branches. Sometimes nearly every twig was found injured. There was also an occasional mirid bug on the foliage. A few Proterhinus beetles were beaten from dead twigs.

Insects of Olapa (*Cheirodendron gaudichaudii*)

Only scattered trees of this kind were noted. They were not particularly eaten by insects. Two species of leaf bugs were occasionally collected. The work of the large weevil *Nesotocus munroi* was not noted, but Mr. Ignacio, the forest ranger, later sent us 20 of the beetles which he collected from an olapa tree along the Laupahoehoe trail. The larvae of this beetle live in the decaying bark of dying trees, reaching full growth about the time the bark is entirely decomposed, then they burrow into the wood to form pupal cells, from which the adult beetles issue in due time. They do not injure healthy trees, living only in dying or dead branches or dying trees.

Insects of Mamake (*Pipturus albidus*)

The mamake was rather scarce, but where found was usually considerably attacked by insects, though not particularly injured. The caterpillars of the Kamehameha butterfly (*Vanessa tammeamea*) were found feeding on the foliage but not numerous. A leafminer was numerous in the leaves, the larvae of a small moth. None was reared, but it is probably *Gracilaria neraudicola,* which has been reared from mamake leaves in several localities on the island of Hawaii. A few larvae were found feeding in terminal buds similarly to what larvae of *Epagoge infaustana* do on Oahu, but none matured to demonstrate the identity of the species. A jassid leafhopper, apparently a new species of Nesophrosyne, was found in small numbers.

Insects of Akala (*Rubus hawaiiensis*)

This native raspberry was one of the abundant undershrubs occurring in dense thickets in large areas. Its leaves were considerably eaten by the caterpillars of a small pyralid moth (*Phlyctaenia endopyra*). The stems were conspicuously injured by borers, the larvae of a longicorn beetle (*Plagithmysus vitticollis*). These larvae tunnel more or less spirally beneath the bark of living stems, not killing them outright but crippling them. However, the shrub thrives as dense thickets in spite of this injury. In dead stems were found medium-sized shiny oval weevils of a new species of Oodemas. There were caterpillars feeding in pith of dead stems from which the moth *Hyposmocoma chilonella triocellata* was reared.

Insects of Ohelo (*Vaccinium calycinum* and *Vaccinium peleanum*)

The first mentioned species of Vaccinium occurs commonly in clumps in the forest reserve as well as above. The leaves were badly eaten by the caterpillars of a red moth (*Phlyctaenia pyranthes*). None was reared, but the moths came abundantly to light. Berries were scarce and some of them were being eaten by the larvae of a moth, a species of Heterocrossa. None was reared, so the species was not determined. Bushes of *Vaccinium peleanum* were found common in the sparse scrub above the mamani forest, at an elevation above 8500 feet. Berries were more abundant and a few were found eaten similarly to those of the lower species, but no moths were reared. It no doubt would be the same as the species which infests ohelo berries of the Kilauea region: *Heterocrossa inscripta.* Many of the stems were found to have been injured by borers, and a few of the borers were found. They ate in the living stems and worked more or less spirally around the stem. From larvae in stems taken to the laboratory, one beetle was reared, which proved to be a new species somewhat related to a beetle that bores in Raillardia on the summit of Haleakala, Maui.

Insects of Tree Fern (*Cibotium chamissoi*)

This species of tree fern was plentiful in the jungle of the forest reserve. No insects were found feeding on the living ferns, but the stems of dead fronds were well populated with insects; some feeding on the decaying tissues of the stem;

some predacious on other insects; and others using the hollow stems as a retreat or hiding place. The most abundant insect feeding in these dead stems was *Proterhinus ferrugineus.* The slender brown weevil, *Pentarthrum prolixum,* which is generally abundant in fern stems everywhere, was very scarce. Another weevil, *Dryophthorus insignis,* was also scarce. A nitidulid beetle was common. Among the predators were seven species of carabid beetles: *Colpodiscus lucipetens, Mecyclothorax konanus, Metrothorax deverilli, Thriscothorax varipes, Colpocaccus hawaiiensis, Mecyclothorax* near *vulcanus, Thriscothorax* near *bembidioides.*

From all of the foregoing, it is seen that, in general, the forest of the region is not suffering significantly from insect attack. One insect common to the region, which has not been mentioned, is the Fuller's rose beetle (*Pantomorus godmani*), which is an immigrant insect, whereas all of the others that have been considered are native insects. The Fuller's rose beetle is an indiscriminate feeder. The beetles feed on the foliage of nearly every kind of tree, shrub, fern and herb. They have often been quite injurious to small seedling trees planted in the region.

It is significant to note that although there are quite a number of kinds of insects present whose habits are feeding on dead and decaying wood, no termites were found in the region. Any other regions where we have studied the insect relations to the trees, the large termite, *Neotermes connexus,* has been found inhabiting dead branches and logs of about every kind of tree. Whether the elevation was higher than where this termite exists, remains yet to be determined. It will be a problem of interest to ascertain just what is the upper limit in the distribution of this termite, which inhabits the native forests of all the islands, not, however, coming down onto the lowlands, though it has been found as low as about 500 feet on Oahu. It is also worthy of mention that none of the immigrant ants of the lowlands were found in the Nauhi region; also that a single specimen of the Chinese grasshopper was found on grass in the vicinity of the Nauhi nursery. It is rather remarkable that it should have reached this place so far from the coast regions where it has been known in grassy regions and cane fields only the past six years.

Leaf Scald Disease of Sugar Cane in Hawaii

By J. P. Martin, C. W. Carpenter and D. M. Weller

CONTENTS

I. INTRODUCTION

Leaf scald, a vascular disease caused by *Bacterium albilineans* Ashby, is considered by plant pathologists to be one of the eight more important diseases of sugar cane. The other seven diseases of major importance are mosaic and streak (caused by so-called viruses), Fiji and sereh (possibly of virus origin), gumming (*Bacterium vascularum* [Cobb] Grieg-Smith), smut (*Ustilago scitaminea* [Rab.] Syd.), and downy mildew (*Sclerospora sacchari* Miy.).

Explanation of Plate: Manoa varieties affected with leaf scald disease.

A. and C. Portions of leaves of Manoa 185 and 160, respectively, showing the typical narrow white lines on blades and sheaths.

B. Longitudinal section of top of stalk (M. 160). Typical appearance of the red discolorations of the vascular bundles and portions of the adjacent parenchyma. The red discoloration is most conspicuous in the nodes.

D. Lower portion of stalk with side shoots illustrating symptoms of the chronic phase of leaf scald (M. 160). Etiolated portions of leaves, white lines on the leaves and internal red discolorations of the stalk are shown.

Leaf scald disease has been responsible for severe economic losses to the sugar industry in several districts of Australia, causing the elimination of the desirable Mahona variety and preventing the culture of other promising varieties. In Java, "Gomziekte," now considered to be leaf scald, has caused serious damage on young plant cane and, as in Australia, has curtailed the spread of desirable commercial canes.

Hawaii has remained comparatively free from the more serious cane diseases as graphically shown in the following chart. Only two of the above-mentioned eight major diseases are known to occur here, namely, mosaic and leaf scald. The former disease, then known as Yellow Stripe, was first recorded here in 1908 by Lyon (17, p. 2), who identified it with "Gele Strepenziekte" of Java. Leaf scald was first identified here in December, 1930, by the authors, although, according to the observations of several plantation managers, it has been present sporadically for a decade or longer. Its occurrence has been noted thus far only in variety test plots. While no commercial losses have been experienced, the disease is regarded as potentially important.

The object of this first paper on the subject is to present the outstanding characteristics of leaf scald disease not only as it occurs in Hawaii, but as it occurs in other countries as well. Many illustrations of the features of the disease and growth habits of affected canes, gross and microscopic diagnostic symptoms and characters, supplement the description. It is hoped that this paper will serve to acquaint the personnel of the sugar industry with the disease so that it may readily be recognized.

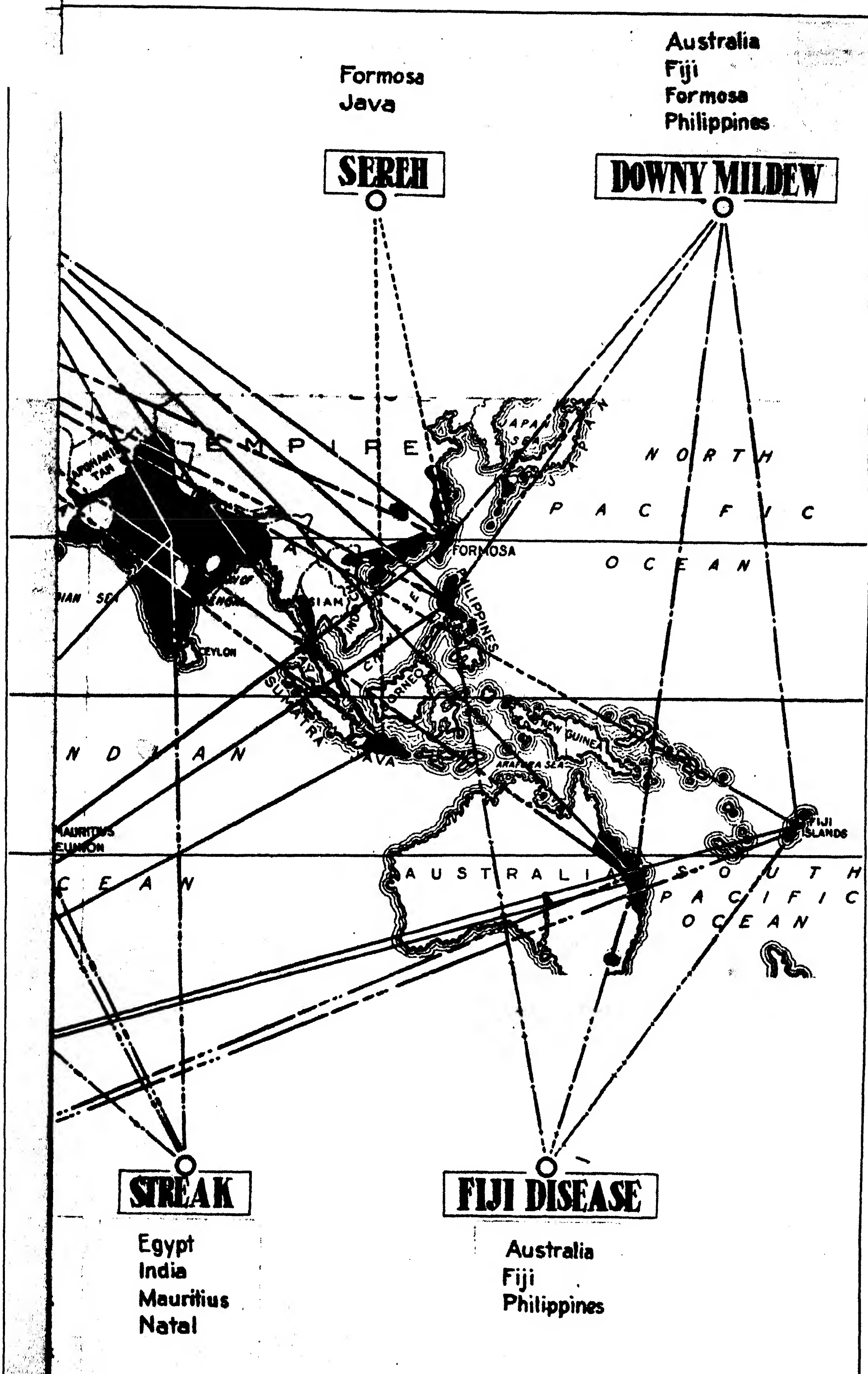
Leaf scald disease is discussed in this paper with special attention to the following considerations: History and geographic distribution; gross and microscopic symptoms; distribution of *Bacterium albilineans* in the tissues; inoculation experiments; varieties affected and resistance of varieties; economic importance; transmission and means of control.

II. HISTORY AND GEOGRAPHIC DISTRIBUTION

Our knowledge of leaf scald disease is largely due to Dr. G. Wilbrink, directress and pathologist of Cheribon Sub-Experiment Station, Cheribon, Java, and to D. S. North, pathologist for the Colonial Sugar Refining Company, Ltd., Sydney, Australia.

In 1915, Groenewege (12) erroneously concluded that this disease, known in Java as Gomziekte, and the Australian gumming disease, caused by *Bacterium vascularum* Cobb, were identical. "Gomziekte" became known in other countries as "Java gumming" disease, which led to further confusion with the true gumming disease.

In 1920, Wilbrink (29) published a very comprehensive paper on Gomziekte, the Java gumming disease, and showed conclusively that it was distinct from the true gumming and sereh diseases. North and Lee (20), in 1924 discussed the



ES OF THE WORLD

FIG. 1.

A stalk of the variety Manoa 185 badly affected with leaf scald disease (chronic phase). Note the development of side shoots and drying of top. This plant exhibited both the red vascular bundles in the stalk and the white stripes of the leaves (July 7, 1931).

similarity between the leaf scald disease of Australia and Java gumming disease and affirmed the conclusion of Wilbrink that Java gumming was distinct from true gumming disease. North (21, p. 9) concluded that the Javanese gumming disease and the Australian leaf scald disease are in all probability identical. The simultaneous studies by Wilbrink (*loc. cit.*) in Java and North (21) in Australia, the research of each being unknown to the other, resulted in practically identical accounts of the symptoms of leaf scald and detailed descriptions of the causal organism.

The history of this disease in Java may be summarized from the account by Wilbrink as follows:

Prior to 1913, this disease was referred to as Hundred Brown disease because a variety known as Hundred Brown was primarily concerned. Later the disease was considered the same as Australian gumming disease following the publication of descriptions of this disease by Cobb (7, 8 and 9). In 1915, Groenewege (12) published a paper under the title "The Gum Disease of Sugar Cane Caused by *Bacterium vascularum* Cobb," and again in 1917 a paper (13) entitled "The Gum Disease of the Sugar Cane and the Means of Checking It." Wilbrink (*loc. cit.*, p. 1401) excused a reopening of the subject in the following statement: "The reason is that it is not shown in the above-mentioned treatises that the cause of gumming disease has been found, or that the proper means of dealing with it are proposed."

Wilbrink refuted the conclusion of Groenewege that Gomziekte and Australian gumming disease were the same, and avoided the assumption of other Java investigators that Gomziekte was a form of sereh. Her conclusion that Gomziekte was distinct from Australian gumming disease was based on experimental evidence and critical comparisons of the symptoms of the two diseases, as well as careful studies of the causal organism. Her conclusions were confirmed by North (21). Following the publications of Wilbrink and North various writers noted the occurrence of this disease in other countries.

The history of leaf scald disease in Australia and Fiji was summarized by North (22, p. 1) as follows:

In Australia, its presence has been traced back with certainty to 1911, and it seems likely that it was introduced some time prior to 1900, along with cane plants from either New Guinea or Java. This is strongly suggested by the early history of Mahona (No. 22 of Tryon's 1896 collection of New Guinea canes), which, although a splendid variety in other respects, was said to "mature too early and die off," particularly in tropical districts. It is still liable to "die off" in this manner, but only as the result of leaf scald disease, to which it is one of the most susceptible varieties known.

In these early times, the disease was probably widely distributed through the cane areas of Australia and Fiji, because Mahona apparently failed through "dying off" in practically all districts except the Richmond and Tweed Rivers of New South Wales. In these two districts it yielded highly profitable crops, being widely grown for many years and becoming the main standard variety for a time. They apparently escaped infection by some chance. However, leaf scald was introduced from the Clarence to the Richmond in a consignment of 46 tons of N. G. 16 cane plants in 1912, and seems also to have been introduced to the Tweed

FIG. 2.

Chronic form of leaf scald disease on Manoa 160. Note the presence of side shoots and white stripes on their leaves. The leaves on the top of this stalk manifested definite symptoms (April 25, 1931).

by some unknown means about the same time. In 1915-1917 it became conspicuous in the Mahona crops in both these districts, and during the next few years caused very severe crop losses. . . . On this account the variety finally had to be discarded, or "ran out," as the farmers say, and more resistant kinds grown in its place.

It is likely that leaf scald similarly caused not only Mahona but also other susceptible varieties to "run out" in earlier times in many other districts, but on this point no definite records are available. This is strongly suggested, however, by the fact that the standard varieties now cropped in Australia and Fiji are for the most part highly resistant. Also the planting of Clark's Seedling (H. Q. 426), the Gorus (N. G. 24, N. G. 24A, N. G. 24B) and Pompey (7R428) has lately been seriously curtailed in certain districts (e. g., Mossman, Cairns, Johnstone River, Rarawai) owing to its ravages. All of these varieties, too, may be classed as moderately resistant, all being much less susceptible than Mahona.

Hurried surveys made by the writer in 1911 and 1915 have served to establish its prevalence in those times in the Cairns, Johnstone River, Herbert River and Mackay districts. Some suspicious cases of Clark's Seedling suddenly dying off (not definitely diagnosed as leaf scald, however) were also observed in the Childers district.

In the Philippines, Lee (14), 1921, described a red vascular disease of sugar cane which was observed in several districts. Lee states (pp. 432, 433):

There has been observed at Lamao, Bataan; Alabang, Rizal; Carmencita, Pampanga; in Mindoro and sparsely distributed throughout Occidental Negros a disease which we are calling red vascular disease characterized by a wilt of the leaves and by reddened vascular bundles. The disease is distinct from the published description of sereh in that there is no mention of a wilt of the leaves in the case of sereh, nor is there in the case of this Philippine disease the profuse stooling of the affected canes as described for sereh in Java. The disease is most common on H 109, altho it has also been observed on Louisiana Striped and Negros Purple. Inasmuch as Negros Purple is said to be very resistant to sereh in Java, this constitutes another reason for believing it to be distinct from sereh. The disease is also quite distinct from wilt and red rot, either of which from the written description might be confused with this trouble.

Lee (15), after visiting Java in 1923, concluded that the Philippine red vascular disease and Java gumming were identical.

North and Lee (20), 1924, in Honolulu, Hawaii, after carefully studying preserved specimens and photographs, discussed the similarity between leaf scald disease of Australia and the Java gumming disease described by Wilbrink (29). These investigators in confirming the view expressed by Wilbrink commented as follows: "The Java gum disease described by Miss Wilbrink is decidedly different from Cobb's gumming disease of sugar cane and since it may lead to confusion to continue with such a name, it seems desirable to adopt the rather descriptive name leaf scald as used in Australia for this trouble."

In Formosa, the disease was first observed in 1918 on canes imported from Java, according to Dr. T. Miyake, director and pathologist, Government Research Institute, Taihoku, Formosa, in personal communication. It was named "Haku Jyo Byo," meaning white stripe disease. Symptoms of leaf scald disease have been noted in the various cane-growing districts of Formosa but the economic losses have been considered of minor importance.

FIG. 3.

Typical symptoms of leaf scald disease on Manoa 160. Side shoots with white lines on the leaves are shown (February 26, 1931).

The disease was recorded for the first time in Mauritius in 1928 by Tempany (27, 28), where it undoubtedly had existed for many years previous to this date but had been confused with gumming disease caused by *Bacterium vascularum* Cobb. Leaf scald is now known to be widespread over the island. It attacks chiefly White Tanna and Striped Tanna canes and results in losses both in field and factory. Experiments have been conducted wherein losses of from 5 to 11 per cent of cane weight occurred and the sucrose content reduced as much as 16 per cent. White Tanna is tolerant to the disease and fair yields are being obtained from this variety under favorable climatic and cultural conditions. The disease not only affects the standing cane but greatly inhibits the germination of planted cuttings and ratoons.

Christopher and Edgerton (6) mention a disease of cane in Louisiana characterized by white stripe symptoms which resemble those of leaf scald. No organism was isolated and the disease appeared of little importance.

III. OCCURRENCE IN HAWAII

Occasionally, during the past eight years, symptoms suggestive of leaf scald disease of sugar cane have been observed and studied. In the early part of 1930 several new local varieties on the island of Kauai manifested the disease symptoms described in this paper. In a number of instances free-hand sections of fresh material from affected stalks and leaves showed the presence of motile rod-shaped bacteria within the vascular bundles.

In September, 1930, Royden Bryan, of the agricultural department of this Station, collected diseased specimen material of the variety Manoa 160 at Onomea Sugar Company on the island of Hawaii and forwarded it to the pathology department for diagnosis. This material exhibited the typical external and internal symptoms of the chronic phase of leaf scald disease.

The occurrence of a large number of diseased stools in the several plots of Manoa 160 at Onomea provided abundant material for observation and afforded an opportunity to identify the disease. The cane in these plots consisted of plant as well as first and second ratoons, about six to eight months old. The plots were in wet localities at elevations of 800 to 1200 feet.

It was evident at once that the diseased cane manifested all of the symptoms typical of the chronic phase of leaf scald disease and the symptoms of the acute phase were present on an occasional stalk. The symptoms characteristic of leaf scald are described in detail on pages 157-166. At Onomea, the leaf stripping, development of more or less etiolated "lalas" (side shoots) and suckers, as well as the internal vascular discolorations typical of leaf scald disease, were conspicuous features.

The history of the individual plots indicated that the disease had been transmitted from plot to plot by infected cuttings. In an upper field of young plant cane there was some evidence indicating that certain of the cuttings had acquired the disease from infected knives. This area had been rogued several times

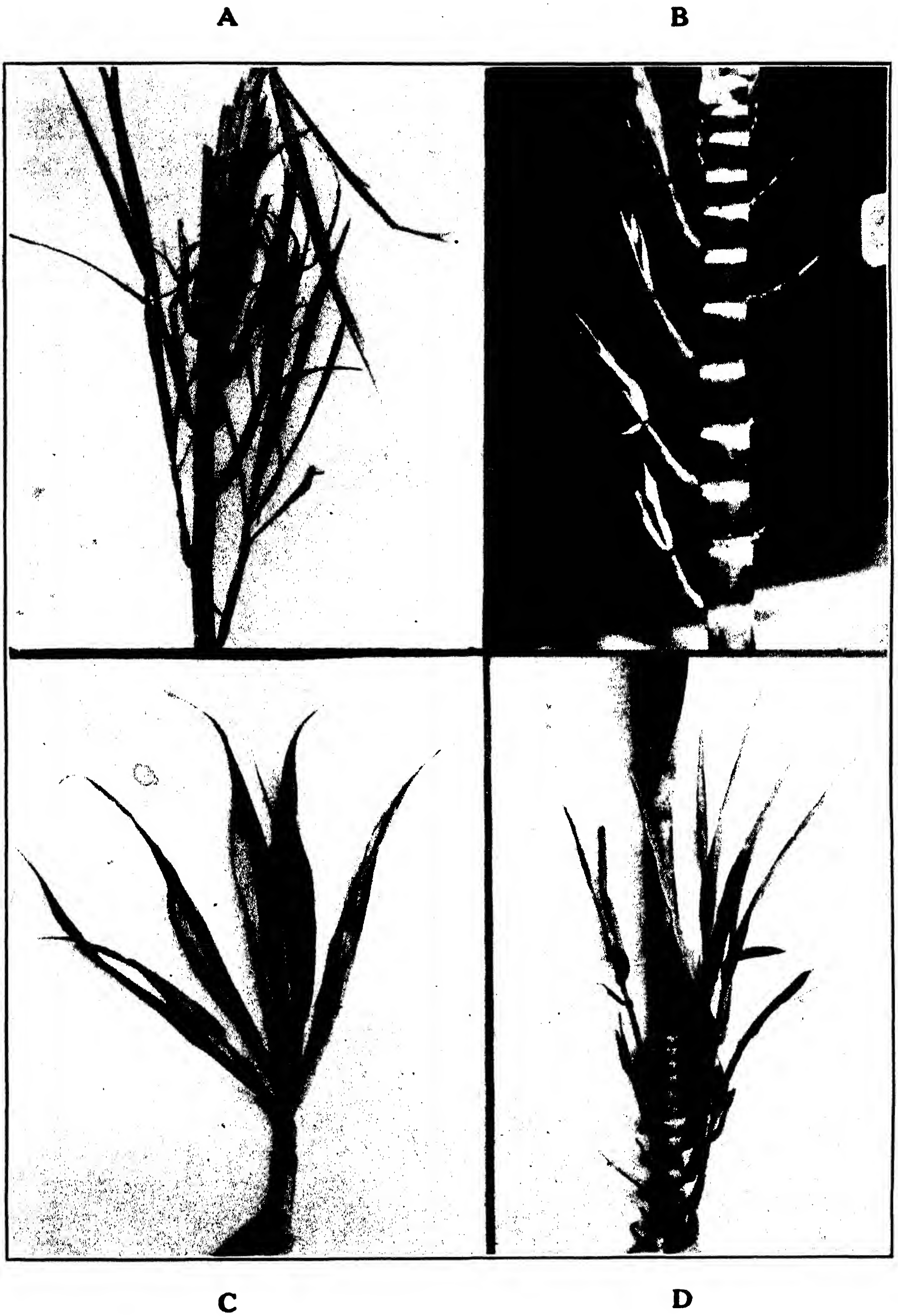


FIG. 4.

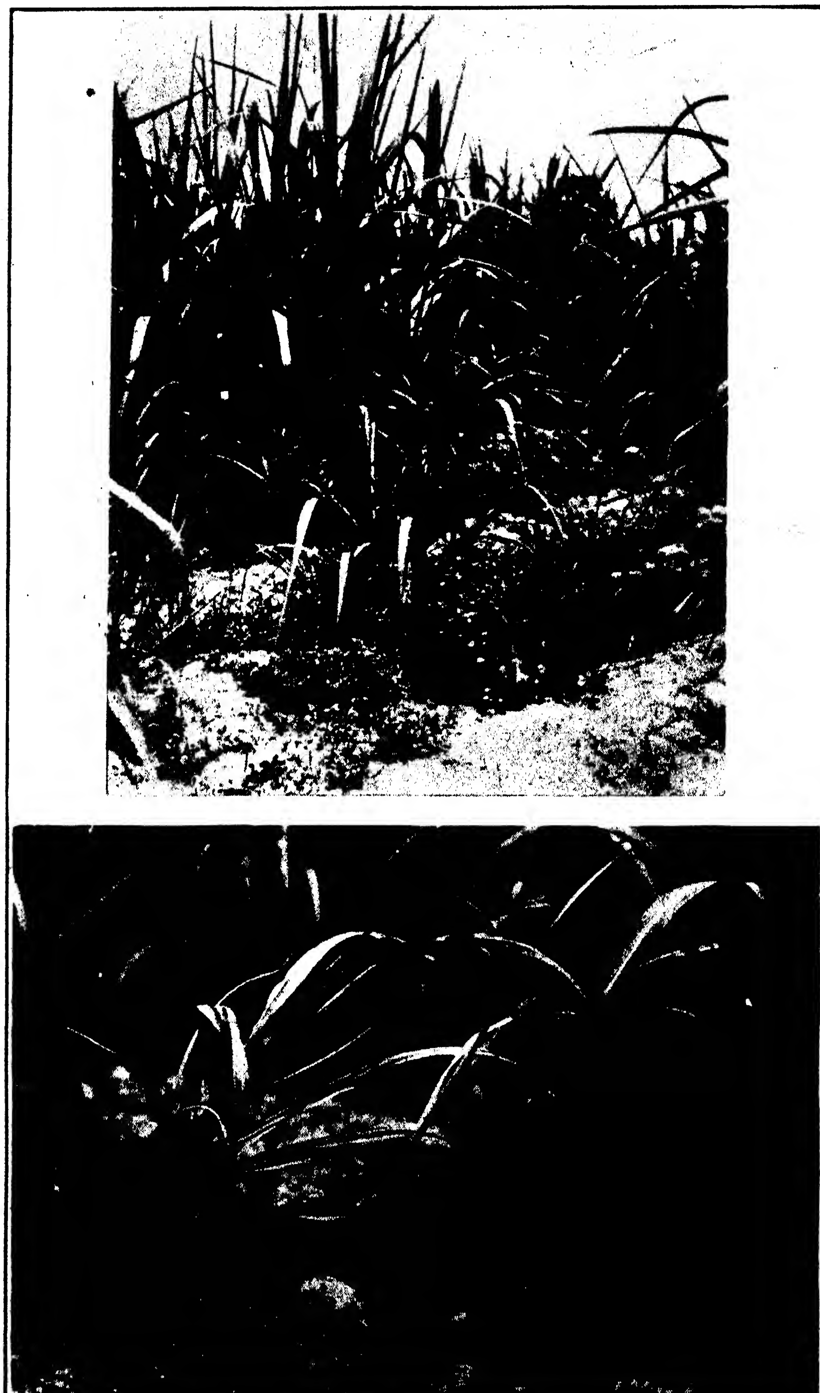
A. E. K. 28 cane affected with leaf scald disease (Cheribon Sub-Experiment Station, Java, 1929).

B. Showing the development of side shoots on stalk of Badila cane (Broadwater, N. S. W., Australia, 1929).

C. Shoot of Badila cane showing characteristic upward curling and withering tips of leaves (Innisfail, Queensland, Australia, 1929).

D. Illustrating the occurrence of numerous side shoots (Badila cane, Innisfail, Queensland, 1929).

A



B

FIG. 5.

A. A stool of H 109 cane in the foreground affected with leaf scald. Note depressed growth in comparison with the healthy cane in the background. (Tarlac, Luzon, P. I., 1929.)

B. Leaf scald disease on the variety Pampanga Red. The older leaves were beginning to wither, while the younger leaves were chlorotic and showed typical white lines. (Tarlac, Luzon, P. I., 1929.)

to eliminate diseased stools. However, a number of slightly affected stools remained and since the cane was small, having grown slowly as a result of the unfavorable wet weather which prevailed in the summer of 1930, the planted cuttings could be easily pulled from the soil. Only the leaf striping symptoms were present and in general only one of the several shoots in a stool appeared to be diseased. Many of these stools were pulled out and examined. It was observed in almost every case that the one affected shoot on the cutting was the one developed from the uppermost eye. While this observation might indicate a habit of the diseased cane, it seemed rather to indicate infection from the cut end of the seed piece.

A preliminary examination, microscopically, of free-hand sections of the affected tissues of the leaves and of the growing points of the stalks, as well as of bacterial smears made from such tissues, indicated that the disease was caused by bacteria. The presence in the affected tissues of motile bacteria which agreed in shape and size with the causal organism of leaf scald as described by Wilbrink and North was observed. A corresponding plugging of the vessels of the vascular bundles was conspicuous. Incidentally, it may be of interest that pure cultures of the first isolations, i. e., the series 438, 441 and 443, in subsequent inoculation tests proved to be the pathogen (see Fig. 21, Table II and p. 187).

The gross symptoms and the results of the observations, microscopically, when considered in conjunction with the very complete descriptions of leaf scald disease by Wilbrink and North, indicated beyond reasonable doubt that the disease affecting the Manoa 160 and other varieties in Hawaii was leaf scald.

In order to determine whether or not the disease attacking Manoa 160 was infectious and could be mechanically transmitted, a series of direct inoculations was carried out by Martin at Onomea, December 22, 1930. An infusion was prepared by macerating the growing points of diseased plants of Manoa 160 in sterile, distilled water. The growing points used showed reddened vascular bundles, one of the symptoms of the chronic phase of leaf scald disease. On the leaves of the plants from which the diseased growing points were selected, very sharply defined white lines, another symptom of the chronic phase, were present. The macerated material was next filtered through several thicknesses of cheesecloth so that the larger particles of plant tissues were removed from the infusion.

Healthy plants of Manoa 160 were selected in the field at Onomea for an inoculation test. First a number of plants were injected hypodermically near the growing point with sterile, distilled water to serve as controls. Then another series of selected healthy plants were inoculated near the growing point with the infusion. Within three weeks symptoms corresponding to those of the chronic phase of leaf scald disease began to develop on the plants inoculated with the infusion (Fig. 6). The control plants remained healthy. These preliminary tests demonstrated that an infectious disease was affecting the variety Manoa 160. The results of these tests are included in Table II.

In the meantime four varieties of susceptible cane were being grown in a quarantine house at Honolulu to provide material for inoculation tests with pure cultures of the suspected pathogen. Although it was evident that the disease was

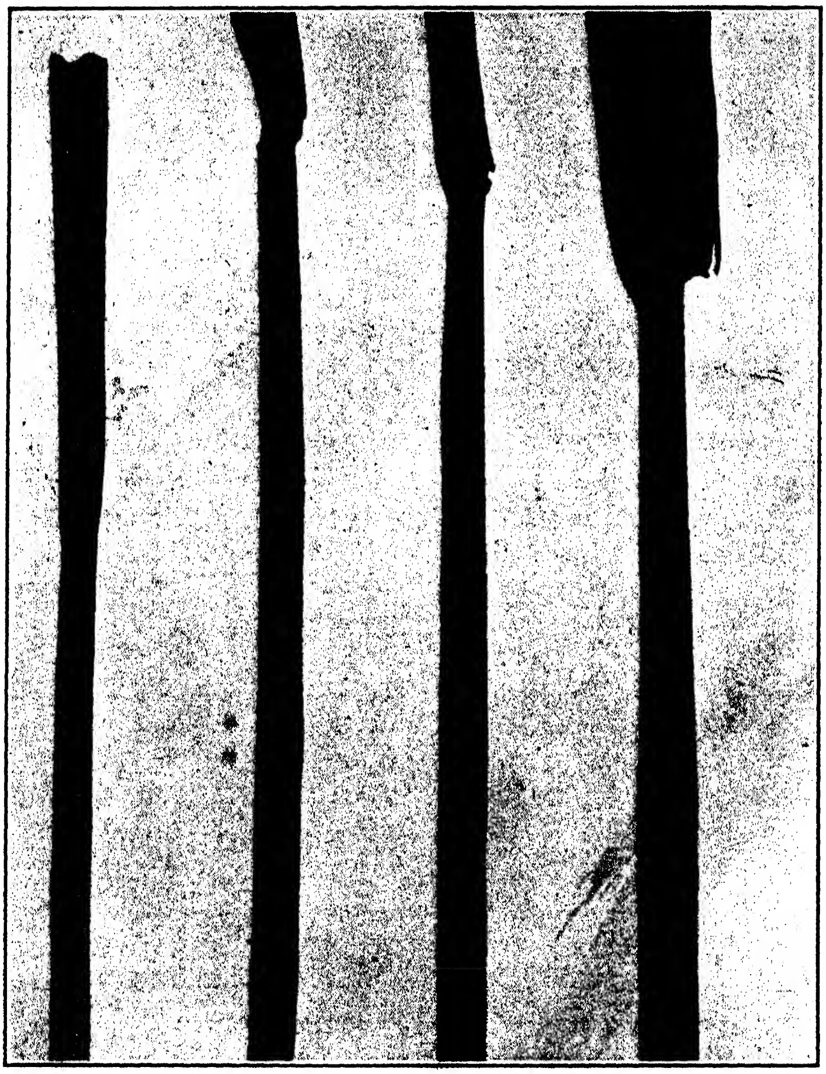


FIG. 6.

White lines, typical of leaf scald disease, extending from the leaf blades onto the leaf sheaths. These lesions developed on healthy Manoa 160 as a result of inoculations with infusion from diseased cane. (February 26, 1931.)

leaf scald, bacteria closely resembling *B. albilineans* Ashby having been isolated in pure culture, it was necessary to produce the disease by inoculation with the suspected pathogen, and prove its identity with the causal bacterium of leaf scald disease, to complete a positive diagnosis. Carpenter, in December, 1930, had demonstrated the presence of slender, short, rod-shaped bacteria in the affected tissues of Manoa 160 and H 109 collected respectively at Onomea Sugar Company, Hawaii, and Oahu Sugar Company, Ltd., Oahu. Several strains (439B, 439X) of one type of bacteria isolated from the mentioned H 109 cane proved to be the pathogen in inoculation tests conducted in the quarantine house at Honolulu. Subsequent isolations by Martin and Carpenter from Manoa 160 collected at Onomea yielded many additional pure cultures of bacteria similar to *B. albilineans.* Such bacteria proved capable of producing the typical symptoms of leaf scald disease when healthy stalks of Manoa 160 were inoculated at Onomea Sugar Company. These experiments are discussed in more detail on page 187 and the results are included in Table II. These studies showed conclusively that leaf scald disease occurred in Hawaii.

While the inoculation tests were being conducted a survey of all of the plantations of the Islands was made in order to determine the distribution of the disease. In addition to the plots mentioned at Onomea a few sporadic cases of the disease were found in the Hilo District on the island of Hawaii; a number of cases were found in several small plots of seedling canes at Koloa, Kauai; none were found on Oahu other than the two stools mentioned on page 185; and no evidence of the disease was found on the island of Maui. In order to confirm the diagnosis of the disease on Kauai, Weller made a series of isolations and conducted inoculation tests at Koloa. These tests are discussed in detail on page 187 and the results included in Table II.

IV. DESCRIPTION OF SYMPTOMS

Wilbrink (*loc. cit.*) and North (21) recognized two distinct "phases" of leaf scald, namely, the chronic and the acute. As late as 1919, according to North, the two phases were regarded in Australia as two separate diseases, but following a more intensive study they were shown to be two forms of the same disease. In fields affected with leaf scald it is possible to observe both phases, one phase frequently grading into the other. For convenience each form will be described separately.

Chronic phase: The earliest symptom of the disease is recognized by the presence of elongated, narrow, white stripes on the leaf blade. These stripes may extend the entire length of the leaf including the leaf sheath, or may be only a few inches in length before they blend into the normal leaf color. The stripes vary in width from a fine line to one-eighth of an inch, although occasionally they may be one-quarter of an inch in width. These narrow stripes on cane leaves are illustrated in Fig. 3 and in the colored plate opposite page 145. The color of the stripes varies from pure white to a yellowish white. Occasionally minute reddish-brown spots are scattered throughout the chlorotic tissue, or a thin red line extends up the middle of the white streak. These spots are due to necrosis of the tissue, which

FIG. 7.

The narrow white lines characteristic of leaf scald extend onto the leaf sheaths. These lesions were produced by inoculating healthy plants (Manoa 185) just below the growing point, with a pure culture of *Bacterium albilineans*. (July 7, 1931.)

FIG. 8.

The two stalks of Manoa 186 at the left illustrate the wilted and inward curved leaves characteristic of the acute phase of leaf scald. The side shoots are more characteristic of the chronic phase of the disease. At the right is shown a healthy stalk of this variety. (July 7, 1931.)

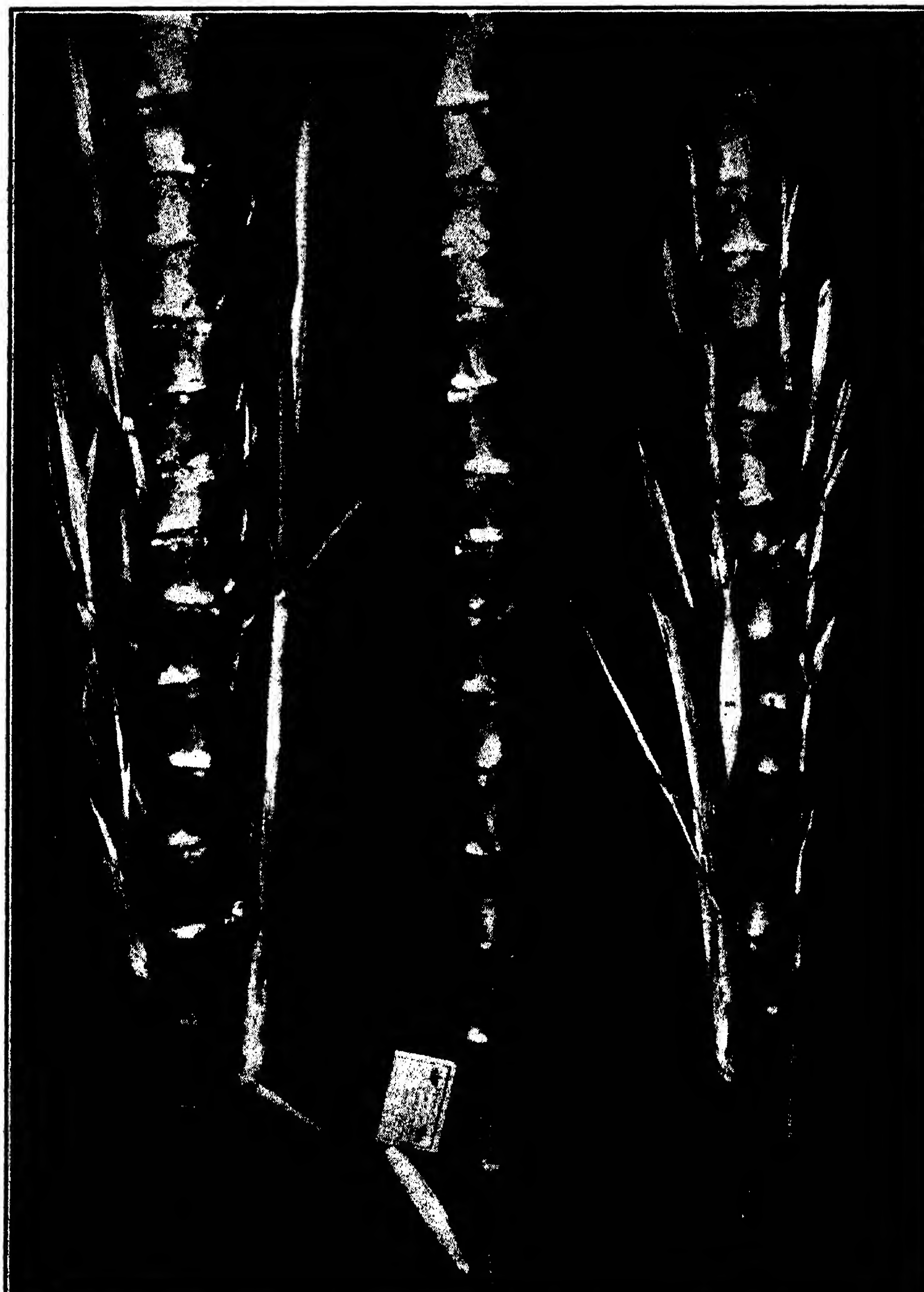


FIG. 9.

The development of side shoots on diseased stalks of Manoa 185. The tops of these stalks showed the acute phase (wilt) of leaf scald. (July 7, 1931.)

in advanced stages results in an irregular reddening of the lesion. A partial or complete etiolation of the cane tops may be present, especially in young ratoons. The stripes follow the vascular bundles of the leaves and sheaths and may include one or more bundles. The margins of the stripes are sharp and well defined. The reason for their sharply defined edges is discussed under the histology of the disease on page 174. The stripes are usually visible on both sides of the leaf but in some cases they may be restricted to either surface. As the lesions mature they become broader, especially on the old leaves; they sometimes lose their sharpness of outline, becoming more diffuse. The final development is the dying of the tissue involved, which may take place at any point in the streak but usually starts at the margin of the leaf blade and travels downward. These stripes may be found on the very young leaves of the spindle which are as yet unrolled.

As already mentioned, the characteristic stripes often extend onto the leaf sheath and may assume a purplish color. These symptoms are shown in Figs. 3, 6 and 7, as well as in the colored plate. One or more streaks may be present on the leaf blade or leaf sheath, according to the severity of infection.

A literal translation of the name of the causal agent of leaf scald disease, *Bacterium albilineans,* signifies a bacterium producing white lines; this in itself is highly descriptive of the outstanding symptom of the disease. On very young cane such straight, narrow white lines are the only diagnostic symptom.

However, on older cane other definite symptoms are to be considered. The affected stalks may produce side shoots, locally known as "lalas," as illustrated in Figs. 1, 2, 4, 8 and 9. At first only one or two side shoots develop, followed by others both above and below this point, and in a short time a large number of "lalas" will have been formed. In a badly diseased stalk it is not uncommon to find that every bud on the stalk has sprouted. The leaves of these side shoots also frequently manifest typical white streaks, as described above, which are extremely useful for diagnostic purposes, especially if for any reason the stripes on the cane top have been obliterated due to the death of the top.

The side shoots or "lalas" are as a rule very weak, the young leaves being more or less etiolated; this condition is illustrated in the colored plate. These side shoots, which seldom attain a length of over 18 to 24 inches, soon wither and die. At the base of a diseased stool numerous weak suckers develop and the symptoms already described may occur on this type of growth.

Upon splitting an affected stalk, bright red longitudinal lines or streaks are visible, particularly at the nodes (see colored plate; and Figs. 10, 11 and 12). This discoloration is due to a reddening of the vascular bundles and adjacent tissues which have been invaded by the causal organism. The discolored bundles are more numerous at the nodes but they may extend through the internodes. Such reddened fibres are more conspicuous in the more mature portion of the stalk in the nodes from which "lalas" have developed. They are also found near the growing points of the main stalks as well as in the side shoots and suckers. These symptoms, shown in the colored plate, are discussed in more detail on page 170.

In summarizing, the important symptoms of the chronic phase of the disease are as follows: (1) the presence of whitish narrow stripes on the leaf blade and leaf sheath, withering of leaf tissue at the distal end of the stripes and more or less

FIG. 10.

Internal symptoms of leaf scald disease (Manoa 185). Red discoloration of the vascular bundles is most conspicuous at the nodes. Red discolored tissues are conspicuous in the upper nodes near the growing point. Lysigenous cavities also are shown. (July 7, 1931.)

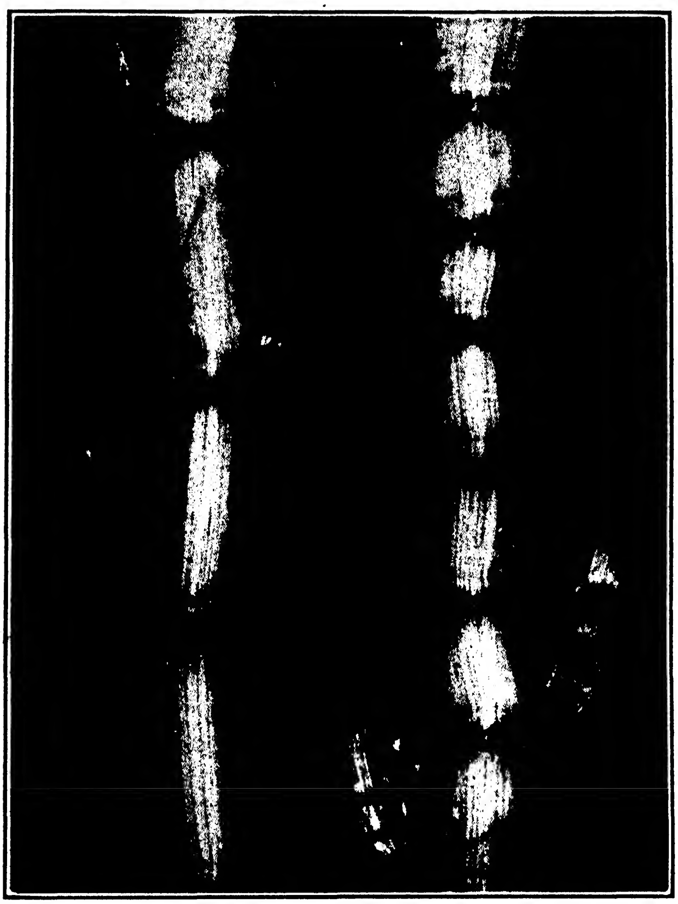


FIG. 11.
Split stalks of diseased Manoa 185 showing red discolorations particularly at the nodes. (July 7, 1931.)

A B

FIG. 12.

A. Longitudinal section of a stalk of E. K. 28 showing reddish vascular bundles which are more pronounced at the nodes. Such discoloration is highly characteristic of leaf scald disease. (Cheribon Sub-Experiment Station, Java, 1929.)

B. Leaf scald disease on Badila cane. Longitudinal section showing discoloration of vascular bundles at nodes and development of side shoots. (Innisfail, Queensland, Australia, 1929.)

FIG. 13.

The stand of cane on the left was grown from healthy cane cuttings which were cut with a sterilized cane knife. The open stand on the right was grown from healthy cane cuttings which were cut with a cane knife used previously to cut diseased cane. Many stools failed to grow as indicated by the irregular stand. Dr. G. Wilbrink is in the background. (Variety E. K. 28, Cheribon Sub-Experiment Station, Java, 1929.)

etiolation of the leaves; (2) the production of side shoots or suckers in affected stools with the characteristic white stripes on the leaves, or with white leaves; and (3) the reddish discoloration of the vascular bundles, particularly at the nodes.

Acute Phase: The acute phase of the disease is quite conspicuous in the field and is characterized by a sudden or acute wilt of the plants, especially during periods of dry weather or when the cane approaches maturity. Individual stalks, entire stools or even large areas may develop this form of the disease. North (22, p. 19) states regarding the acute phase:

> Many whole stools and parts of other stools, sometimes even whole fields, may suddenly wither and die in a most alarming fashion. The wilting takes place just as if the canes attacked were suddenly deprived of their roots, neighboring unaffected canes meanwhile remaining green and of vigorous healthy appearance. The effect on the crops resembles that caused by the Queensland cane grub, so much so that farmers in North Queensland sometimes attribute to grubs damage which is really caused by leaf scald.

Bell (3, p. 21) comments as follows on the diagnosis of this phase of leaf scald:

> In the acute form it is often difficult to make a positive diagnosis and to do this it is necessary to search the base of affected stools for the side shoots and suckers which bear the very narrow white stripes upon the blades and sheaths of the leaves.

Plants manifesting symptoms of the acute phase seldom exhibit the typical white stripes on the leaves of the cane top.

In Hawaii the chronic phase of the disease has been most commonly observed although several cases of the acute form have been found. An acute form of leaf scald disease on Manoa 160 is shown in Fig. 8. The upward curling of the leaves is characteristic of plants manifesting this phase.

V. HISTOLOGY

The most conspicuous of the symptoms of the chronic phase of leaf scald disease, as described on page 157, is that of the narrow, white or cream-colored lines with sharply defined margins running parallel to the vascular bundles of the leaves and sheaths. At a certain stage in the development of these white lesions appear very small pink to red-brown dots, which may become confluent, forming a very narrow, pinkish line throughout the center of the lesion. The direction and appearance of these lesions suggest that one or more of the vascular bundles have been affected.

When transverse sections of such lesions are examined it is seen at once that a vascular disease is being dealt with, for the tracheae, or water-conducting tubes of the bundles, are seen to be wholly or partly occluded with a gum-like substance, which varies from a pale to a deep brown color (Fig. 14).

It is hoped that the following histological study may facilitate the diagnosis of the disease, especially in obscure cases, and also contribute to a better understanding of its fundamental nature as well as to the related problems of its transmission and control.

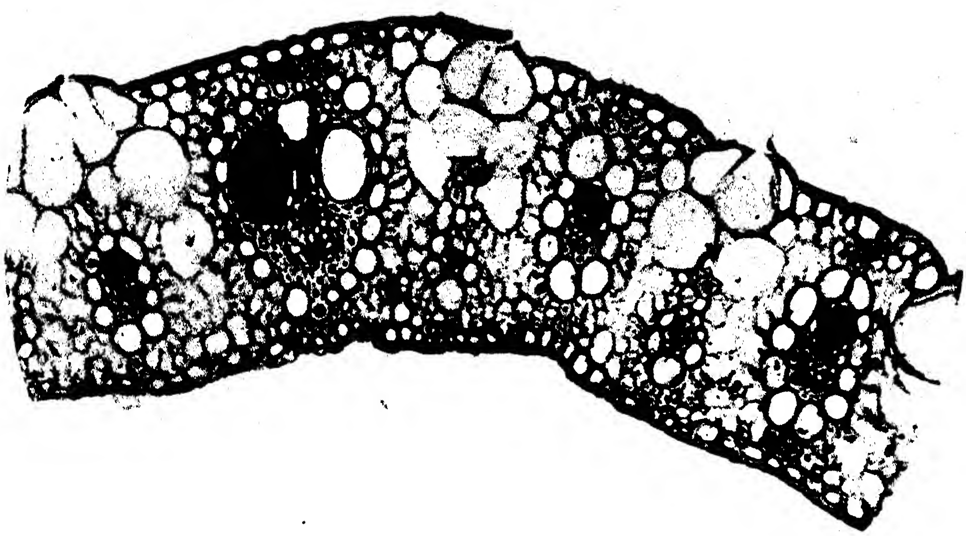


FIG. 14.

Transverse section through one of the narrow white lines on a leaf of a cane plant of the variety Manoa 160 affected with leaf scald disease, showing the vessels, or water-conducting tubes, of a number of the vascular bundles to be occluded by a gum-like substance (X 147).

Methods and Materials

Fresh as well as fixed and stained material of both phases of the disease was used in this study. Sliding microtome sections of fresh material mounted in water offered a convenient method of studying the living pathogen *in situ*. Material was killed and fixed in formalin-acetic-alcohol (5), Bouin's picro-formol (16), Allen's "B-15" (1), Meves' fluid (10), Milovidov's chromic acid—potassium dichromate—formalin fluid (11), by Champy-Kull's modification of Altmann's method and of Benda's method (18), in Regaud's fluid (10), and in Murray's Formol-Müller (18).

Sliding microtome sections were made from some of this preserved material just before it was run up through the alcohol series for embedding, stained and mounted in glycerine. After the material was embedded in paraffin, serial sections were made and stained by the same methods as were the sliding microtome sections.

A number of staining techniques were used to demonstrate both the general anatomical features of the host tissues and to stain the causal organism in the tissues. For the former safranin combined with either Delafield's or Haidenhain's haematoxylin, with anilin blue, or with light green was useful. Flemming's triple stain was excellent for this purpose.

Because the gum in the xylem cells of the bundles was always stained heavily by the safranin, destaining with acid alcohol had to be done quite precisely. Unless this was done the details within the gum mass were obscured. The nicest detail within the gum mass was always obtained by Murray's method of using Haidenhain's haematoxylin for staining mitochondria and bacteria.

A number of attempts were made to demonstrate the pathogen *in situ*. This proved rather difficult to do. Ziehl's carbol-fuchsin was first tried according to North's suggestion (21, p. 33), but for some unknown reason this method failed not only when preceded by Bouin's picro-formol, but when following formalin-acetic-alcohol, Allen's "B-15," Regaud's and Meves' as well. Neither Champy-Kull's method nor those suggested by Dufrenoy (10, 11) succeeded. The most satisfactory method proved to be that of Murray (18). (See Figs. 15, A, B; and 16.) This method proved to be not only simple in technique but precise in its staining and the color differentiation of the host tissues was excellent for the purpose of making photomicrographs.

The following stains were used: Safranin*† and Anilinblau, alc.† [Lot No.] 210, from Dr. G. Grübler & Company, Leipzig; Fuchsin Basic†, Lot No. 765 and Orange G—Crystals*†, from The Coleman & Bell Company, Norwood, Ohio; Hematoxylin C. P., Certification No. FH 7, from National Aniline & Chemical Company, Inc., New York, N. Y.; and Gentian Violet*† from The Harmer Laboratories Company, Philadelphia, Pa.

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* Lot number not available.

† Dye content not available.

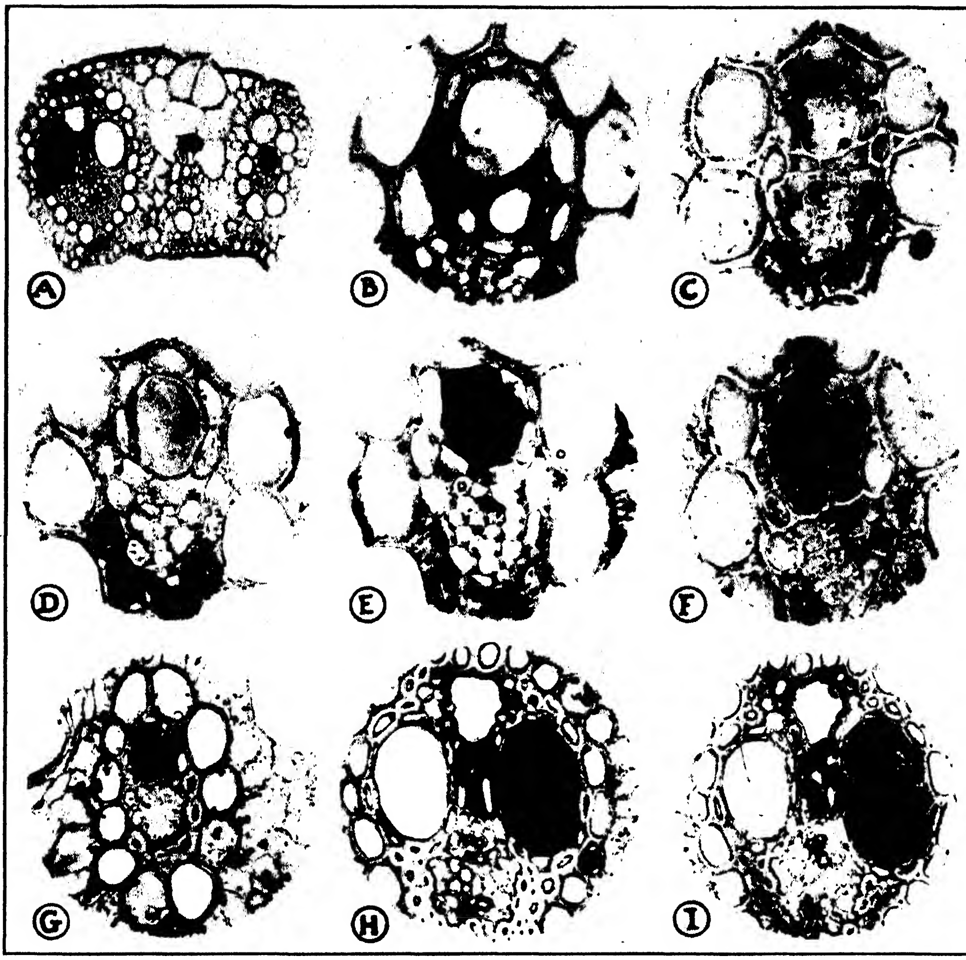

FIG. 15.

Transverse sections of vascular bundles of cane leaves affected with leaf scald disease: A, showing one of the vessels, or water-conducting tubes, of a large rhomboid bundle to be normal while another vessel of the same bundle is occluded with a dark, gum-like substance (X 90); B, the amber-colored gum-like substance, in which bacteria can be distinguished, beginning to invade a vessel of one of the small, round bundles (X 534); C, a vessel of a bundle similar to that shown in B in which the amber-colored gum-like substance containing distinguishable bacteria has completely occluded the invaded vessel (X 534); D and E, vessels of bundles similar to the ones shown in B and C but at later stages after occlusion, as indicated by the successively darker colors of their occluding gum masses and the absence of distinguishable bacteria (X 534); F and G, occluded vessels of medium-large, oval bundles (F, X 534; G, X 237); H, a larger view of one of the large rhomboid bundles (See A) showing the well-developed lysigenous cavity and the total occlusion of one of the vessels with gum (X 237); I, a bundle similar to the one shown in H (See also Fig. 18). The lysigenous cavity is well advanced. The gum mass of the occluded vessel shows a dark peripheral area with a relatively lighter central area. The remains of a former cross wall, apparently destroyed by the invading bacteria, are seen. The cells lying between the two large vessels and two small areas of the phloem (also seen in H) are discolored (X 237).

Host Tissues Affected

Xylem

When either fresh or fixed and stained sections of lesions of plants affected with leaf scald disease are examined it is readily apparent that there is a total lack of hyperplasia of the affected tissues and that the chief effect of the disease on the tissues is that of the occlusion of the vessels of the bundles with a gum-like substance (Figs. 14; 15, A, E, G, H, I; 17; 18). This gum and the progress of its formation in the xylem cells, whether of the bundles of the leaves, sheaths, or stem, tells much of the story that is to be told about the effects of the disease on the host tissues. In the more advanced stages of the disease, pockets of this gum may be formed also in the parenchyma outside of the bundles, especially at the growing point.

If fresh sections from the advancing area of a very young lesion of a leaf or sheath are examined, it will be seen that as yet no gum has been formed in the xylem cells. Instead, these cells are seen to be filled with rapidly moving bacteria. The first impression one has upon viewing these organisms is that they are too large to be the causal organism of the leaf scald disease. But if one watches carefully sooner or later individual bacteria, whose movements have slowed up, may be singled out. With the aid of an ocular micrometer the size of such organisms was estimated to be approximately 1.0 micron by 0.5 micron. This size compares favorably with the measurements made by North (21) and Wilbrink (*loc. cit.*) as well as with those by Carpenter as given in this paper. The shape of these rapidly moving bacteria appears to be oval rather than that of short rods. The explanation of these apparent discrepancies in both size and shape may be suggested by the facts that the organisms are being viewed when in very rapid vibration, which might make them appear larger than they really are, and this, together with the refraction of light as the result of what is probably a capsule, as demonstrated by Carpenter, may explain their apparent shape.

If sections from a slightly more mature part of the lesion are examined it will be seen that gum has begun to form and partly fill the xylem cells, while the part of the cell unoccupied by the gum may or may not be filled with motile bacteria. If this gum is examined carefully, bodies darker than the surrounding gum mass, closely approximating in size and shape the motile bacteria, are seen. In some cases these are seen to be in restricted motion, while in others no movement can be detected. Such sections were stained and are shown in Fig. 15 B.

In sections from a still more mature portion of a lesion, especially if the pink line has formed throughout its center, this gum mass extends across and completely fills the xylem cells. During this stage, as is shown in Figs. 15, C, D, F; 16, A, B, C, D, individual bacteria may be distinguished, but, usually, no motion could be seen. At this stage also the transverse bundle connection of both leaves and sheaths may be invaded by bacteria and occluded with the gum mass (Fig. 19, F).

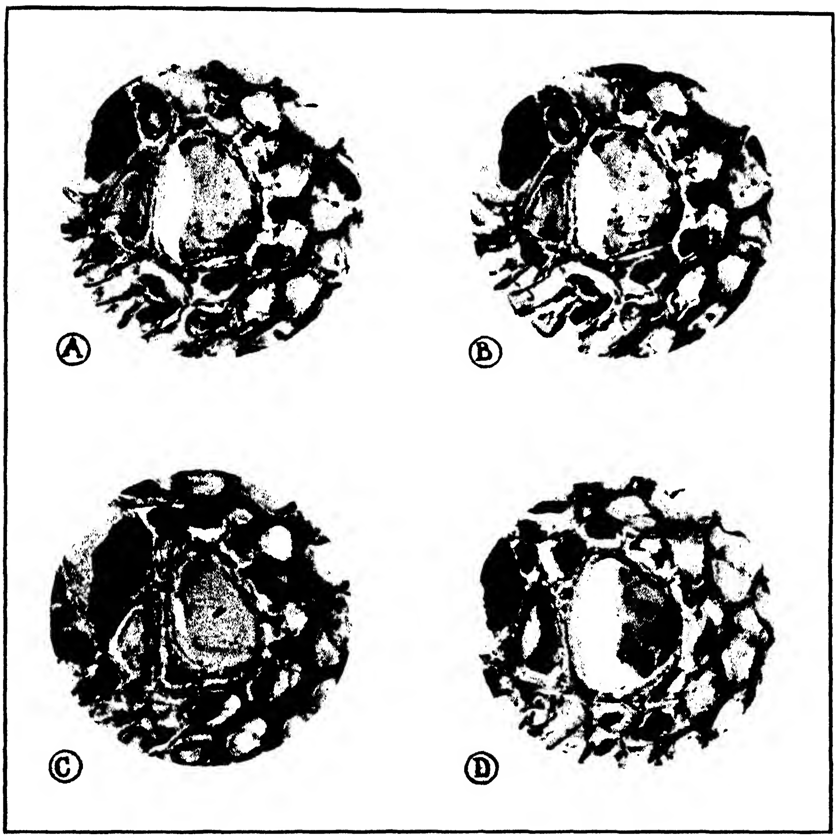

FIG. 16.

Transverse sections of bundles of a stalk of H 109 cane showing vessels occluded with gum-like masses containing bacteria (*Bacterium albilineans*). No external symptoms other than stunting were manifest by the plant from which these sections were made (X 534).

Characteristics of the Occluding Gum

As the lesion advances in age, the color of this gum changes from a light-brown through red-brown to a dark-brown color, photographing in different shades of gray to black, according to its age. Sometimes this color change takes place evenly throughout a given cell (Figs. 15, C, D, E, F, G; 20, C, F). At other times the dark color exists around the margin of the mass with a lighter area in the center (Figs. 15, I; 17; 18). Sometimes cells contain this dark marginal area while the central area is an open channel (Fig. 19, B, C), which suggests that under certain conditions the advancement of the disease may be arrested. Later, when the disease renews its advancement, this channel becomes filled with a freshly formed gum mass, which may explain the condition of the lighter central area surrounded by the darker margin.

The true nature of the gum which occludes the xylem cells is little understood. Wilbrink (*loc. cit.*) calls it "wound gum." Occasionally it gave a slight red reaction with phloroglucin, but this reaction was so slight and so erratic that it could hardly be interpreted to be a true wound gum (30, p. 157). As no swelling could be obtained by soaking it in water, it is doubtful whether it is a true gum at all. According to Smith (24, vol. III), Cobb states that the gum of the Australian gumming disease *(B. vascularum)* is not a true gum.

In another place Cobb (9) states:

> Lenses of high power show the gum to be swarming with microbes of the form known as bacilli. . . . Each microbe has about it a small amount of gummy matter, which is the product of its growth. The gum described as issuing from the sap vessels of the cane has, therefore, two component parts, namely, microbes and a viscous gummy matter. This gummy matter appears to be a new substance, and to it I have applied the name of vasculin.

In view of the possibility of the leaf scald organism possessing a capsule, the possibility of this gum being a built-up mass of the organisms themselves should be considered.

Cell Walls

Many times the middle lamellae of xylem cells occluded with gum appear to have been dissolved (Figs. 15, F; 17; 18). In some cases the entire cell wall has been dissolved (Figs. 15, I; 18).

Lysigenic Cavities

The dissolving action of the bacteria on the cell walls of the host tissues is more commonly found when the organism invades the air spaces, or the schizogenic cavities, called the lacunae, which develop normally just outside of the annular vessels of the bundles and form an internal "ventilating" system of the plant. The action of the bacteria on these air spaces enlarges them by dissolving the cells surrounding them, thus forming the lysigenic cavities (26, p. 98). These cavities in various stages of advancement can be seen in Figs. 14, 15 A, H, I; 17; 19, A, B, D, E, F; 20, A, B, D, F.

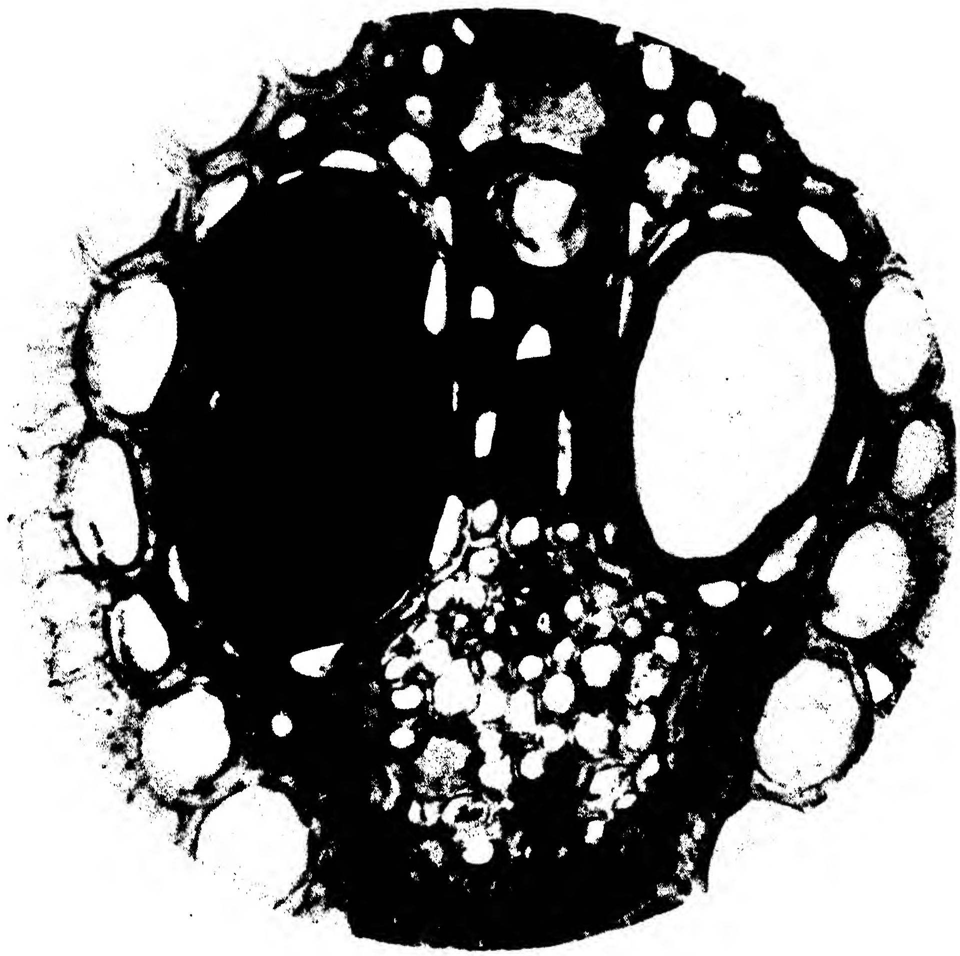

FIG. 17.

Transverse section of a bundle of one of the white lines of a leaf of a cane plant (Manoa 160) affected with leaf scald disease. The lacuna just above the annular vessel is discolored and beginning to be enlarged by the action of the invading bacteria to form the lysigenous cavity. The gum-like masses occluding the two adjacent vessels of metaxylem show dark (older) marginal areas with lighter (more recent) central areas. The middle lamella can be seen in the cell wall separating the two occluded vessels, which is beginning to break down as the result of bacterial action. The xylem cells lying below the annular vessel and the cells of two regions of the phloem are discolored (X 776).

Phloem

In the earlier stages of the disease infection is confined to the xylem cells, but, as the disease advances, apparently the infection invades the phloem (Figs. 14; 15, H, I; 17). This invasion does not affect the phloem evenly, as can be seen in the photomicrographs just referred to. At no time was it possible to distinguish individual bacteria in the phloem in either fresh or stained sections, which makes it uncertain as to whether it is the invasion of the actual bacteria themselves or the diffusion of their secretions that produces this effect. Apparently there is no phloem necrosis.

Other Tissues

Much the same that was said about the phloem can be said of several other tissues. Occasionally cells of the starch sheath were discolored (Figs. 14; 15, A, G). This was true also of the phloem fibers (Fig. 15, F). As with the cells of the phloem, bacteria were not seen in these discolored cells in either fresh or stained sections. The cells of the chlorophyll-bearing parenchyma lost their green color at a very early stage in the development of the lesions, the color fading soonest from the cells nearest the upper surface of the leaf. This agrees with Wilbrink (*loc. cit.*), who states that this accounts for the fact that the white lesions are plainer on the upper surface of the leaf than on the lower. In Hawaii, even the lesions appearing on the outer leaves of the spindle were already quite as bright on the one surface of the leaf as on the other and it was necessary to find a lesion on leaves farther toward the center of the spindle before any great difference could be detected.

In transverse sections through a lesion on a leaf, it was seen that in the region of the lesion the green color was absent not only from the cells of the chlorophyll-bearing parenchyma immediately surrounding the starch sheath but from the large parenchyma cells, which contain chloroplasts and lie outside of this tissue between the bundles, and from the starch sheath itself. This was not true of these same tissues in a region of the leaf immediately adjacent to the lesion which were characterized by their normal, green color. As one passes from these tissues of the lesion region to those of the normal region juxtaposed, this color change takes place within the very narrow limit of one or two bundles and explains clearly the appearance of the sharply defined margin of the lesions. This was true of the sheath in only a slightly less degree.

A depression, or groove, in the outer surface of the sheath was occasionally found running parallel with an occluded bundle. This depression was interpreted as an indication that infection of the underlying bundle took place before the tissues of the sheath were fully developed and prevented their normal expansion. North (21, p. 34) describes this same condition together with that of a split of the tissues lying between the infected bundle and the *inner* surface of the sheath (a further indication of the earliness of the infection). This latter condition was not found on the varieties studied in Hawaii.

While the infection of leaf scald disease is usually confined within the bundles, as manifested by the gum masses within the xylem cells of leaf, sheath, and stalk,

FIG. 18.
An enlarged view of the occluded vessel shown in Fig. 15, I (X 1747).

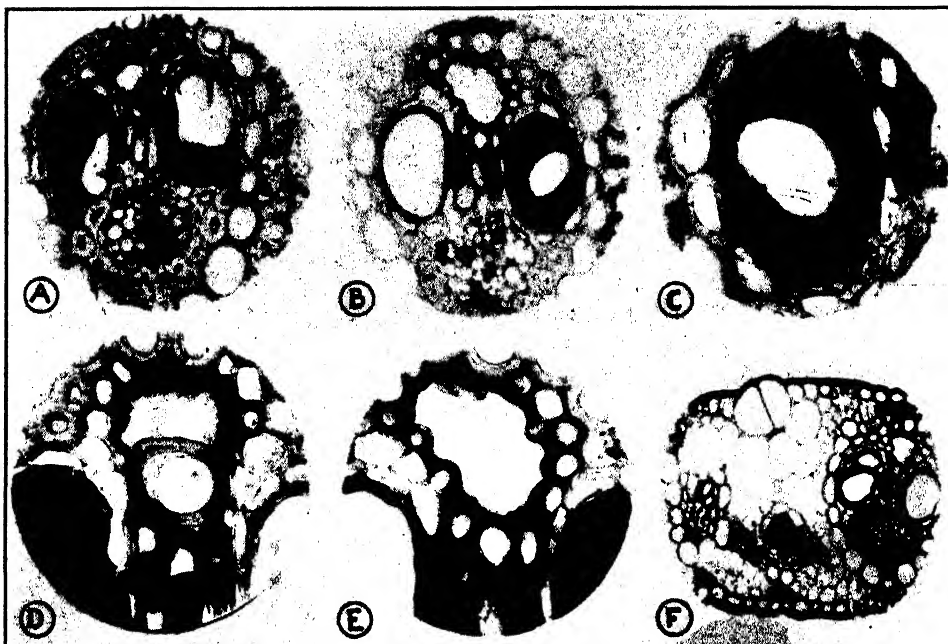

FIG. 19.

Transverse sections of bundles of leaves: A, showing vessels only partly occluded (X 238); B, showing a vessel with all but its central area occluded, and a well developed lysigenous cavity (X 238); C, an enlarged view of the occluded vessel shown in B, a condition frequently found (X 535); D and E, lysigenous cavities in different stages of advancement (X 535); F, showing occlusion of the transverse bundle connections (X 119).

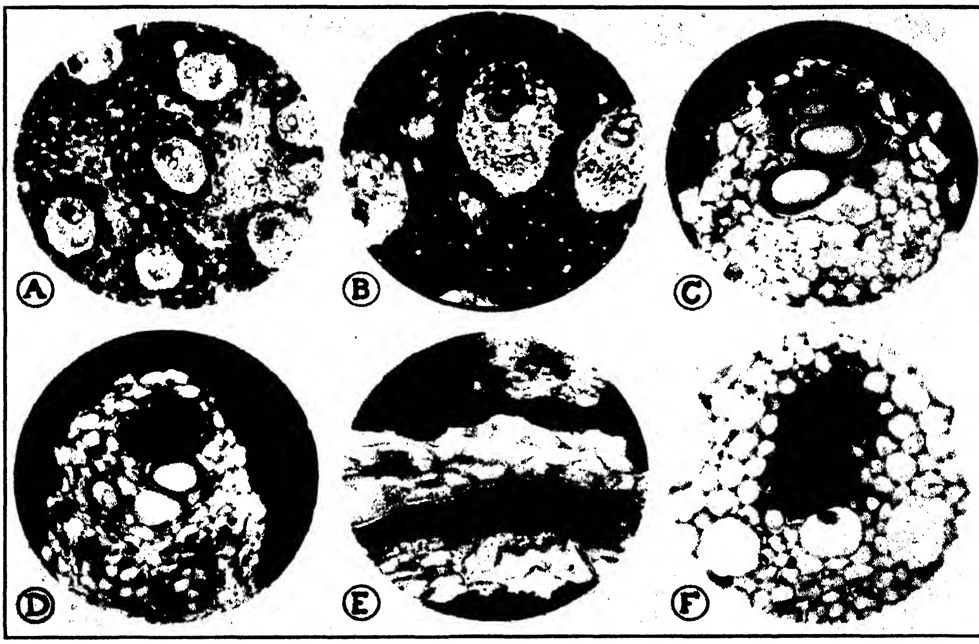

FIG. 20.

Transverse section through an affected cane stalk near the growing point, showing how the vessels of the bundles have become occluded with a gum-like substance very soon after they are differentiated and how the parenchyma cells lying between them have already become of a dark color; a longitudinal section of one of the bundles of the stem after it has changed the course from a perpendicular direction and just before it passes from the stem to the leaf sheath is shown in E. (X 238.)

this is not always the case, for, where the tissues are soft, just below the growing point, the disease invades the parenchyma tissue between the bundles, forming reddened pockets of gum. These pockets can be seen in the colored plate. When examined microscopically these pockets were seen to be composed of partially collapsed or dead parenchyma cells filled with a granular gum mass resembling in both texture and color that which occluded the xylem cells. Not only was it present within these cells, but filled the spaces between the cells as well. Occasionally cracks or cavities occurred, especially in the more advanced stages of the disease. In the gum masses no bacteria could be distinguished.

If stained sections taken from the region of the stem just below the growing point are examined, it will be seen that not only are the xylem cells of the newly differentiated bundles already occluded with gum, but the parenchyma cells lying between the bundles are affected as well (Fig. 20, A, B, C, D). In the newly differentiated bundles of the growing point, which lead to the leaf sheaths, these vessels also are already occluded (Fig. 20, E). In the newly formed vessels of the sheath the same thing is true (Fig. 20, F). It is apparent from these photomicrographs that the organism invades the xylem cells very soon after being differentiated in the growing point. In Fig. 20, F (as well as in others) this invasion is clearly illustrated. Here, three xylem cells lying in a row show the order of their differentiation. The lowest and youngest of these three and two others at about the same stage of differentiation, one to its right and one to its left, are as yet uninfected. The middle and upper cells of these three perpendicular cells have already been occluded, the uppermost and oldest showing evidence of having been invaded first.

VI. THE CAUSAL ORGANISM

Bacterium albilineans Ashby was readily isolated from the affected tissues of leaves, leaf sheaths, spindles and nodes of affected plants. The medium recommended by Wilbrink (*loc. cit.*) was found satisfactory for the isolation and cultivation of the bacterium. The agar medium was prepared according to the following modified formula:

Distilled water	1000	cc.
Peptone (Bacto)	5.	gms.
Potassium phosphate (Dibasic)	0.5	gms.
Magnesium sulphate	0.25	gms.
Agar	15.	gms.
Cane sugar	10.	gms.

The above listed ingredients, with the exception of the sugar, were placed in the hot distilled water and the whole steamed at 15 pounds for 15 minutes. The concoction was then filtered and 10 grams of cane sugar dissolved therein. The medium was adjusted to a final reaction of pH 7.0 to pH 7.5 and sterilized for 15 minutes at 15 pounds. For a liquid culture medium the same formula was used omitting the agar. Subsequent experience has indicated that pH 6.8 is more favorable for growth, at least for cultures in cultivation for some months.

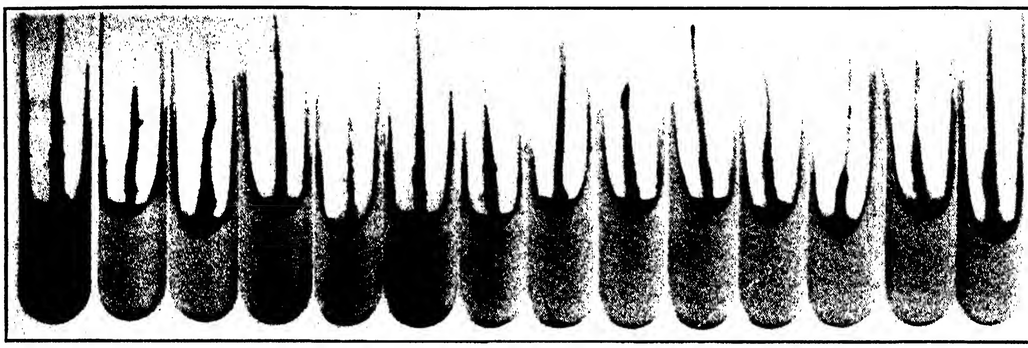

FIG. 21.

B. albilineans Ashby. Six-day-old sub-cultures on Wilbrink agar (X½).

From left to right: No. 438E (Manoa 160), Onomea, Hawaii; 439B (H-109), Waipahu, Oahu; 441W (2), 441W (4), 443, 443I, 445 (Manoa 160), Onomea, Hawaii; 446C (Wailuku 12), Koloa, Kauai; 447C (Manoa 160), reisolation of 439B; 448A (seedling Yellow Tip X 26-C-59), Hakalau, Hawaii; 451A and 451B, (26-C-182), reisolation of 439B; 452A and 452I (Wailuku 12), Quarantine House, Honolulu, reisolation of 439B. (Photo June, 1931.)

Isolation Technique: After surface disinfection of leaf and stalk tissues in alcohol and mercuric chloride solution, small portions were dissected out with flamed knives and planted in poured agar plates. A method yielding at once a high percentage of pure cultures has been described by Wilbrink, wherein the leaves of the spindle are aseptically dissected off, the tip of the rolled spindle leaves repeatedly being cut off with a flamed knife. The end of the inner rolled cylinder of leaves of the spindle, close to the growing point, is then repeatedly streaked on the surface of the several agar plates. The bacterial growth appears after one to two weeks, or later, as a beaded colony growth and series of parallel streaks of watery droplets, or pale yellow, glistening, somewhat raised, masses (Fig. 22). Gradually the color becomes deeper yellow. At first, by transmitted light the growth appears somewhat opalescent, later assuming a characteristic, peculiarly clear, amber, glassy appearance. By reflected light the yellow color very nearly resembles cream buff, Ridgeway (23; Plate XXX, Fig. 19D), becoming later, after three to four weeks, colonial buff (Fig. 21D) and finally deep colonial buff (Fig. 21B). Growth which starts from planted bits of leaf or stalk tissue may first be detected with the hand lens in one to three weeks, as a light colored, gradually increasing mass of bacteria. Under the low power of the microscope this growth is seen to be a finely granular colony with entire edge. The growth of *Bacterium albilineans* about such pieces of planted tissue was often extremely slow. Cultures were obtained also by forcibly inserting the flamed platinum needle into the vascular tissues of the cut end of the streaks of leaf sheaths and stroking the needle on the agar surface or inoculating tubes of agar for dilution plates.

The bacterium was isolated in pure culture many times by the spindle smear method and by aseptically planting bits of tissue of leaf and leaf sheath, as well as the red discolored tissues of the upper nodes of the stalk on agar plates. Reisolations also were made many times from plants diseased as a result of inoculation with *B. albilineans.*

Morphology. Neither Wilbrink nor North named the organism which they studied. The former reported no success in staining the flagella. A knowledge of the disposition of these appendages is necessary to determine the genus of a motile bacterium.

Ashby (2, pp. 137-138) examined a culture of the leaf scald bacterium furnished by North and his brief account of his observations follows:

> The writer has examined a culture kindly furnished by North and has found the bacterium actively motile in young cultures, by means of a single polar flagellum three to five times the length of the rod and has not observed it to liquefy gelatin. The binomial *Bacterium albilineans* is proposed for it on account of the long white leaf stripes of uniform width which are characteristic of the disease.

Ashby did not publish a photomicrograph of *Bacterium albilineans* in this paper, nor elsewhere, according to a review of the available literature.

Bacteria from young cultures on agar or liquid media, were stained by Carpenter, who used Loeffler's method to demonstrate flagellation. Characteristically the local bacterium has one polar flagellum as Ashby has reported for the leaf scald bacterium. This flagellum may be many times longer than reported by

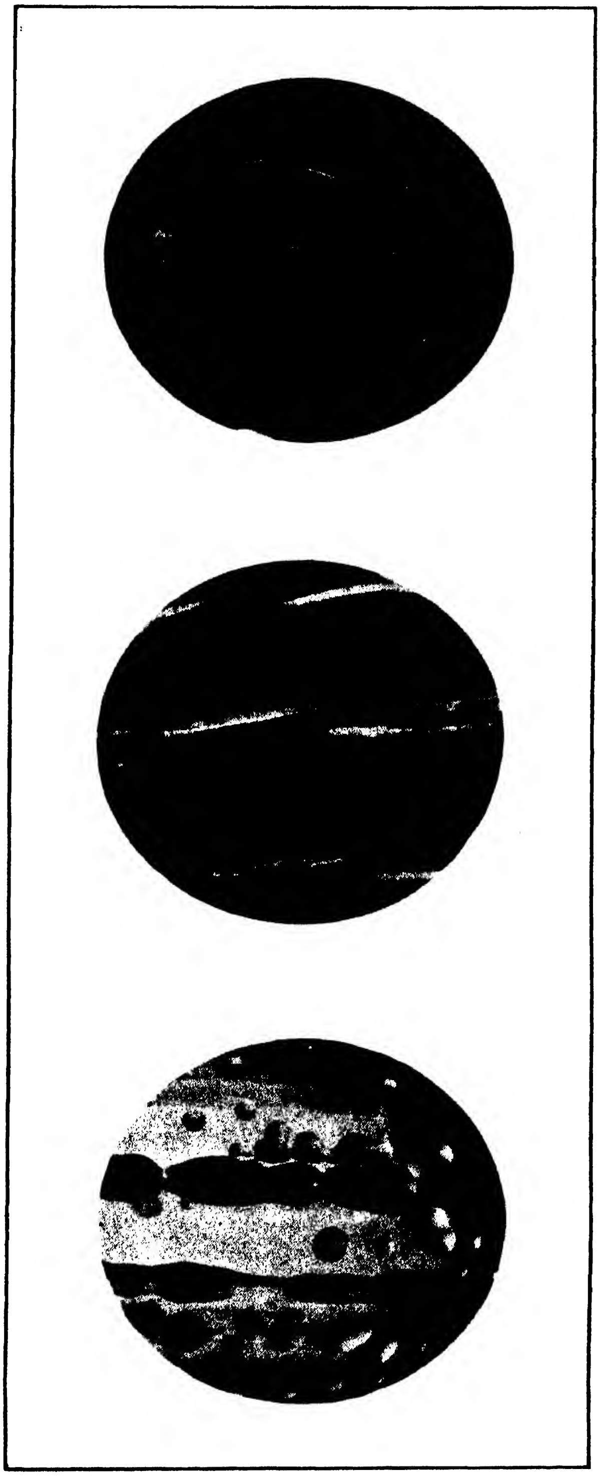

FIG. 22.

B. albilineans. Growth on Wilbrink agar. Spindle smears from Wailuku 12, ten days after inoculation with strain 439B (Yellow). From top to bottom: one-half natural size; portion natural size, and portion X 12, approximately. (March 17, 1931.)

Ashby. Some evidence of the presence of a capsule surrounding the bacterium has been noticed in the preparations made to demonstrate the arrangement of flagella, particularly where 11-day-old cultures on liquid media were used for the studies (Fig. 23 E, F).

The Loeffler formula used was that given by Smith (24, Vol. I, p. 190). Ziehl's carbol-fuchsin was used for staining 1 to 2 minutes after mordanting the dilute, dry, preparations for a similar period of time. Both mordant and stain were heated until steam arose during the process. Good preparations were comparatively difficult to obtain, especially preparations suitable for photographing, which showed single bacterial cells with a flagellum, rather than chains of two or more elements, or masses of many elements. Bacteria with flagella are shown in Fig. 23.

Studies of the characteristics of *Bacterium albilineans* in Hawaii have been confined to such observations as would serve for comparison with the descriptions of Wilbrink and North for the purpose of confirming the identification of the organism. Exhaustive studies have not been attempted with respect to the features mentioned below. The reader is referred to descriptions by Wilbrink and North for more detailed observations.

Table I shows a number of the salient features of *Bacterium albilineans* as found by Wilbrink (Java, *loc. cit.*), North (New South Wales, 21), and Carpenter (Hawaii). This table is followed by a number of pertinent observations reported by Wilbrink, since her paper may not be generally available to investigators of cane diseases. It is hoped that this combined data will prove sufficient for identification of *Bacterium albilineans* in the absence of a complete description by any one investigator. A study of the symptoms of cane where leaf scald disease is suspected, combined with brief studies of any vascular bacterium which may be isolated, should serve to complete the diagnosis.

The dense colonies of several common bacteria, more or less yellow in color, which frequently appear in plate cultures of cane material, should not be mistaken for the characteristically transparent colonies and smears of *B. albilineans.* The rate of growth should serve to eliminate most of the yellow bacteria from consideration, since growth of *B. albilineans* in first isolations rarely is evident to the naked eye in less than 7 days. There is very little chance that *B. albilineans* will be detected with the ordinary nutrient agar medium and if the disease is suspected in localities where it is not known to occur, the use of spindle smears on Wilbrink agar generally serves in 7 to 15 days to develop the characteristic yellowish, transparent growth of this bacterium if it is present. This bacterium, however, is erratic in behavior even on Wilbrink agar and repeated trials are recommended to insure heavy seeding before negative conclusions are reached. Bell and Cottrell-Dormer (4) describe an improved medium for the culture of this bacterium. They discuss this improved technique as follows:

Since the medium evolved in this laboratory may be of considerable assistance in this connection we have deemed it advisable to summarize the work on this particular phase of leaf scald. . . .

The improved germination following the addition of small amounts of sodium sulphite has had a practical application in enabling us to investigate the problem of toxic ions and

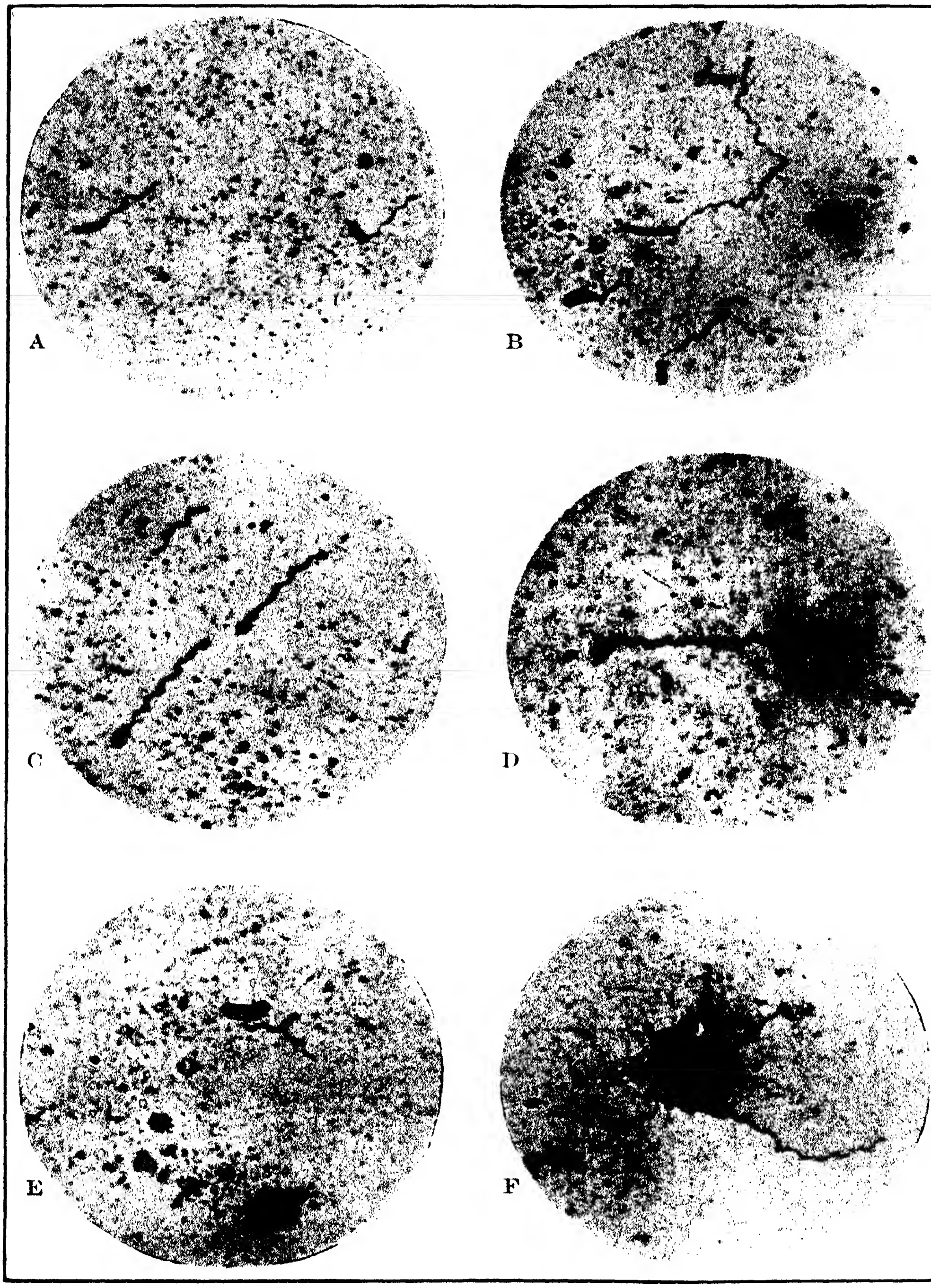

FIG. 23.

Bacterium albilineans Ashby. Flagella stained by Loeffler's method with carbol-fuchsin. A. X 1400 B-F. X 1800

In E and F there is an indication of a capsule; eleven-day culture in Wilbrink liquid medium. A to D from agar slant cultures.

TABLE I

COMPARATIVE CHARACTERIZATIONS OF *BACTERIUM ALBILINEANS* IN JAVA, AUSTRALIA AND HAWAII

	Wilbrink	North	Carpenter
Temperature Relation			
Optimum	27°–28° C.	25°–30° C.	About 25° C.
Maximum	36°–37° + C.	37° + C.	37.5° + C.
Minimum	....	....	....
Thermal death point	52° C.	....	....
Relation to reaction of medium			
Opt. H-ion concentration. (Or reaction Fuller's Scale.)	(+ 20 (Fuller's scale)	(+ 25 (Fuller's scale)	pH 6.4–6.8.
Limits of pH for growth. (Or reaction Fuller's Scale.)	....	(+ 10 to + 25 (F. S.)	pH 5.8–8.5 (Liquid media; Wilbrink formula.)
Growth on meat extract broth and peptone.	Grows freely.	Growth slight.	Very scant growth.
Surface	Cream colored skin.		
Clouding	Moderate to plentiful.		
Sediment / Amount	Fair amount of pale, yellow, flaky deposit.		
Morphology			
Form	Short, slender rod.	Short, slender rod.	Short, slender rod.
Endospores	None.	None.	None observed.
Flagella	(Motile.)	(Motile.)	One polar.
Gram stain	Negative.	Negative.	Negative.
Chromogenesis	Honey yellow.	Buff yellow.	Cream buff (Ridgeway).
Vegetative cells, stained with carbol-fuchsin:			
Length	Nearly 1 micron.	1 micron.	.6 –1. micron.
Diameter	Slightly less than .5 micron.	.2 micron.	.25– .3 micron.
Chains and threads	Present.	Present.	Present.
Capsules	Not mentioned.	Not mentioned.	Apparently present.
Agar stroke. Growth Luster Surface	Colonies appear after one week with undulating edges. Naples yellow—clear to honey yellow or tea brown, moistly shining, edges entire.	Confluent to patchy, entire to very slightly spreading, raised. Glistening to dry, almost white, bluish-gray to yellowish.	Raised, entire, scattered colonies at edge. Glistening, buff to colonial buff, and by transmitted light, honey to buff yellow. Transparent. Peculiar glassy appearance. In age becomes translucent.
Agar colonies.	After 7 to 10 days minute transparent drops, becoming slightly arched discs, moistly shining. By reflected light are creamy white, by transmitted light, transparent honey yellow, to Naples yellow. No abundant slime formation observed.	After 7-16 days first growth evident. Tiny punctiform colonies appearing like droplets of oil or moisture on agar surface. Up to 2 mm. diameter frequently remain punctiform. Large colonies are round, smooth, convex, moist, glistening (more or less); opaque, bluish gray, nearly white by reflected light, translucent light buff yellow by transmitted light. Edges entire. Slightly spreading; soft cheesy consistency. Rarely slimy, thick and tenacious.	Not different in any feature mentioned by Wilbrink and North. Massed colonies by transmitted light have a characteristic yellow to amber, glassy appearance.

is of decided value in enabling isolations to be made with greater rapidity and certainty. The following method of isolating *B. albilineans* from leaf tissue is therefore recommended: Prepare Wilbrink's agar according to the formula given above; dissolve 0.5 gm. of anhydrous sodium sulphite (or 1 gm. of sodium sulphite crystals)* in 9.5 ccs. of cool, freshly autoclaved distilled water, add 1 cc. of this solution to a further 9 ccs. of sterile distilled water; of this second solution add 1 cc. to each 100 ccs. of Wilbrink's medium. The sodium sulphite solution does not require sterilizing but freshly autoclaved water reduces the rate of deterioration. The solution is added before pouring. A portion of a leaf bearing a white pencil streak is well rubbed with alcohol, flamed, and a section of the streak cut out and macerated in a Petri dish in sterile water. The macerated tissue is allowed to soak for one hour, to permit of the bacteria diffusing out, and dilution plates are then made in the ordinary way. In the isolation illustrated on Plate I a pencil streak 2 inches long was macerated in 3 ccs. of water and 0.5 cc. of the suspension diluted to 10 ccs. which was again diluted 20 times; 0.5 cc. of inoculum per plate was used so that the inoculum used in inoculating the Petri dishes here depicted represents 1/1200 linear inch of a pencil streak.

This improved method has not been tried sufficiently in Hawaii to warrant comment on its merit for the cultivation of the local leaf scald bacterium.

Wilbrink (*loc. cit.*) contributed the following data on the bacterium which she investigated. Later evidence now indicates that this bacterium was *Bacterium albilineans* Ashby:

Strictly aerobic.
Sensitive to sunlight.
Sensitive to desiccation.
Secretes invertase.
Does not secrete diastase.

No coagulation, or visible surface growth on milk, though vigorous growth occurs.

No growth with ammonium salts, nitrates, or aspargin, as nitrogen sources. Requires more complicated compounds such as egg albumins or peptones.

Grows in presence of 1 per cent but not 2 per cent NaCl.

Carbohydrates. Poor growth in peptone water without carbohydrates. A fair growth in presence of glucose, saccharose, lactose or maltose. At first growth was difficult to establish with glucose; once started, growth was as good as with saccharose, occurring in the presence of 2½ and 5 per cent, but not 8 per cent glucose. With saccharose, growth slackened in the presence of 10 per cent.

Occurrence of B. albilineans in the cane plant:

The bacteria occur in the leaves, stalks and roots.

Occurrence outside of cane plant:

The bacteria could not be detected in the soil or in the water.

Viability of the bacteria in crusher juice:

Inoculations indicated that the bacteria, if still alive, had lost their ability to produce the disease after remaining 24 hours in the juice resulting from grinding diseased cane stalks.

VII. INOCULATION EXPERIMENTS

Inoculations with suspected cultures of *Bacterium albilineans,* on the island of Oahu, were made in strict isolation in a former quarantine house at the pathology plot, Honolulu, and were restricted to bacterial strains which originated on the island. These inoculations, made by Carpenter February 4, 1931, were

* .005% Na_2SO_3 is found to be the optimum under the conditions of these experiments, and may be expected to vary with other samples of peptone for example.

the first successful ones made with pure cultures of bacteria which proved to be *Bacterium albilineans* and the positive results obtained, combined with observations of the original strain, mentioned below as 439B, and reisolated strains, served to familiarize the writers with the bacterium, confirmed the diagnosis, and facilitated successful inoculations with the proper bacterium in the field.

The bacteria used were isolated from H 109 cane grown in Field 44, Oahu Sugar Company, Ltd. This small plot of cane had been grown from cuttings obtained in Field 83 at Onomea Sugar Company. Inspection of the cane December 19, 1930, at the instance of E. W. Greene, manager, had revealed minor symptoms of the leaf scald type of disease on two leaves of two separate stools. Portions of these affected stalks were wrapped carefully and removed to the laboratory culture room in Honolulu. When the stalks were cut open December 19, 1930, a slight reddening of the vascular bundles of the nodes was apparent. The tissues of the spindle and upper nodes were disinfected in alcohol followed by 1-1000 bichloride of mercury, and after rinsing in sterile water, were aseptically dissected. Portions were planted in agar medium (Wilbrink formula) to permit the development of any organisms present. (Isolation methods found successful are given in greater detail on page 180.)

The isolated bacteria were pure cultures of very slow-growing types. They were given laboratory numbers as follows:

439 A1	439 B (yellow)
439 A2	439 X (isolated by C. C. Barnum)
439 B	

Cane Material for Inoculation: Two flats of sterilized potting soil were planted with each of the following varieties: Manoa 160, Wailuku 12, 26 C 182 and P. O. J. 2714. The three former varieties were considered susceptible to the local disease, while the last mentioned variety was reported susceptible to leaf scald disease in Australia by C. G. Lennox, assistant geneticist. Rapid growth was insured by placing the flats on the warm benches in the seedling propagation house. On February 3, 1931, when the shoots were from ten to fourteen inches high, the flats were removed to Quarantine House No. 2, Honolulu.

Sterile water suspensions of the mentioned bacteria were prepared in small plugged flasks. Two shoots of each variety in each flat were first inoculated in the spindle just above the growing point with sterile water by means of a sterile hypodermic syringe. Then two or more shoots of each variety were similarly inoculated with each of the five strains of bacteria. The object of this experiment was to learn which strains of the five very similar slow-growing bacteria were capable of inducing symptoms of the disease.

On February 16, or after a twelve-day incubation period, several faint, narrow white lines were noted, extending upward and downward from the point of inoculation on the now unrolled leaves of one shoot of Manoa 160 inoculated with strain 439B (yellow). The other two plants of this variety inoculated with this strain showed similar lines February 18, 1931. On the latter date one shoot of Manoa 160 inoculated with 439X also showed definite white lines running down the leaves from the points of inoculation.

Both shoots of the variety 26 C 182 inoculated with the strain 439B (yellow) appeared pale in color February 18, and by February 26, white streaks were conspicuous on several leaves of both plants. Definite symptoms of leaf scald had developed within three weeks on both plants of the variety 26 C 182, which was inoculated February 4, 1931, with the strain 439X.

On February 27, 1931, no further evidence of pathogenicity of any of the used strains was in evidence, with the possible exception of the two shoots of the variety Wailuku 12 inoculated with the strain 439B (yellow), and one shoot inoculated with the strain 439X. One leaf of each of three shoots showed a broad chlorotic or yellow-brown streak running from a point on the midrib in the middle part of the leaf toward the leaf tip. The general wilt symptoms suggested the acute stage described by North.

The variety Wailuku 12 did not grow well in the house, the leaves tending to droop. This tendency was much more pronounced in the shoots inoculated with the strains 439B (yellow) and 439X, both of which had produced leaf scald disease symptoms on the other three varieties of cane. The inoculated shoots of Wailuku 12 later developed a general chlorotic condition, most evident on the lower leaves. A broad, effuse, chlorotic streak was apparent on one or more leaves of each inoculated plant. There was a general wilt reaction combined with a lack of vigor rather than the leaf striping symptoms typical of leaf scald. This condition which did not occur in the controls inoculated with sterile water, nor in those plants inoculated with other strains of bacteria was interpreted as the acute stage of leaf scald.

The bacteria were reisolated March 6, 1931, from the spindle, growing point tissue and nodes, from such a diseased shoot of Wailuku 12 which had been inoculated February 4. Red vascular bundles were conspicuous in the small stalk when the material was prepared for culturing. Bacterial cultures, considered to be *Bacterium albilineans,* were isolated both from spindle and nodes (Cultures 452A, 452 I, Fig. 21).

The variety P. O. J. 2714 showed inconspicuous leaf stripes following inoculation with strain 439X. This variety appeared the least susceptible of the four varieties in the first experiment. The leaf symptoms were slow in appearing and not as clearly defined.

Two flats were planted with cuttings of the variety H 109, January 5, 1931. On February 28 ten shoots of this variety were inoculated hypodermically in the spindle with liquid cultures of strain 439B (yellow). Sterile nutrient medium was used for five controls. On March 17 definite narrow white lines were evident extending upward and downward from the punctures in the new leaves, a few days having elapsed since they unrolled from the spindle. Four days later nine of the ten inoculated shoots had developed clear-cut white lines on one or more of the new leaves, directly associated with the needle punctures.

None of the controls of any variety nor shoots inoculated with bacteria which formed no yellow pigment showed the slightest evidence of white streaks comparable to those produced by the two strains cited.

One shoot of Manoa 160, which had been inoculated with the strain 439B (yellow) was removed from the seed piece February 27, 1931, and taken to the

culture room. Dissection of the small shoot showed that some of the vascular bundles of the nodes close to the growing point were reddened. The bacteria used for inoculation were reisolated, sixteen pure cultures having been isolated from various parts of the smears, or planted bits of tissue.

It might be stated that the conduct of this quarantine house was personnally supervised by Martin and Carpenter and no one had access thereto unaccompanied. Cane material was invariably placed in a tin container and sealed before removal from the house for study. The container was washed in creolin solution and taken to the culture room at the pathological laboratory.

Additional inoculations were made March 7, 1931, in the quarantine house, using other shoots in the same flats, and also a number of ratoon shoots in pots of Manoa 160. The results were the same; practically every shoot inoculated with the strain 439B (yellow) in the several series developed the white leaf streak symptoms in greater or lesser degree within three weeks. The symptoms recurred on the new uninjured leaves subsequently developed by such shoots. Inoculations by needle pricking of expanded leaves of all the used varieties were made, but in no case did the symptoms follow.

These inoculations established the fact that typical leaf scald symptoms could be produced by injecting the spindles with slow-growing bacteria which form a characteristic yellow pigment on the agar medium and morphologically resembled *Bacterium albilineans* as described by Wilbrink, North and Ashby. One similar strain, No. 445A, isolated from the variety Manoa 160 from Onomea, had been already demonstrated to be motile by means of a single polar flagellum.

Seven strains of this type isolated by Carpenter from Manoa 160 collected at Onomea were therefore taken to Onomea Sugar Company, on Hawaii, February 20, 1931, for inoculation purposes. These were strains numbers 438E, 441W (2), 441W (4), 443, 443 I, 445 and 445A (Fig. 21), all of which proved to be parasitic, as recorded in Table II. Other similar strains used at this time for inoculations at Onomea were Nos. 14 and 15, isolated by Martin. The control plants inoculated with sterile water and broth remained healthy.

Nine pure cultures of bacteria resembling those of *B. albilineans* were isolated by Weller, who conducted an inoculation experiment with them at Koloa Sugar Company on Kauai. Healthy plants of the varieties Manoa 185 and 186 were used. A series of direct inoculations was also carried out, by inoculating healthy plants with a hypodermic needle near the growing point with an infusion prepared by macerating diseased tissue in sterilized distilled water. Ten healthy plants were inoculated with each of the nine cultures and a like number used for the direct inoculations. From 70 to 100 per cent of the several series of plants inoculated developed definite symptoms of leaf scald disease (Fig. 7). Ten healthy plants which were inoculated with Wilbrink's broth served as controls. These remained healthy throughout the tests. Detailed results of these experiments are included in Table II.

TABLE II

RESULTS OF FIELD INOCULATIONS

	ISLAND OF HAWAII Variety—Manoa 160 Inoculations made February 20, 1931 Final observations recorded April 22, 1931												ISLAND OF KAUAI Varieties—Manoa 185 and 186 Inoculations made March 24-26, 1931 Final observations recorded May 29, 1931										
Stalk Number	Distilled water	Wilbrink's broth	Direct inoculations*	Culture No. 14	Culture No. 15	Culture No. 438E	Culture No. 441W(2)	Culture No. 441W(4)	Culture No. 443	Culture No. 443-I	Culture No. 445	Culture No. 445A	Wilbrink's broth	Direct Inoculations	Culture C	Culture D	Culture E	Culture F	Culture H	Culture I	Culture J	Culture K	Culture N
1	—	—	+	+	+	+	+	—†	—†	+	+	+	—	—	+	+	+	—	+	+	+	+	+
2	—	—	+	+	+	—†	+	+	+	+	—?	+	—	—	+	+	+	+	—	+	+	+	+
3	—	—	+	+	+	+	—	+	+	+	+	+	—	+	+	+	+	+	+	+	+	+	+
4	—	—	+	+	+	+	—	+	+	+	+†	+	—	+	+	+	+	+	+	+	+	+	+
5	—	—	+	+	+	+	+	+	+	—	+	+	—	+	+	+	—	+	+	+	+	+	+
6	—	—	+	+	+	+	+	+	—†	—	+	+†	—	+	+	—	+	+	—	+	+	+	+
7	—	—	+	+	+	+	—	+	+	+	+	—	—	—	+	+	+	+	+	+	+	+	+
8	—	—	+	+	+	+	+	+	+	—	+	+	—	+	+	+	+	+	—	+	+	+	+
9	—	—	+	+	+	+	+	+	+	+	+	—	—	+	+	—	+	+	+	—	—	+	+
10	—	—		+	—	+	+	+	—†	+	—	+	—	+	+	+	+	+	+	+	+	+	—
Number positive	0	0	9	10	9	9	7	9	7	7	8	8	0	7	10	8	9	9	7	9	9	10	9
Per Cent Positive.....	0	0	100	100	90	90	70	90	70	70	80	80	0	70	100	80	90	90	70	90	90	100	90

* Inoculations made December 22, 1930, with an infusion prepared by macerating diseased tissue. Final observations recorded February 20, 1931.
† Pokkah boeng symptoms or dead spindle.
Culture E—One acute stage.

VIII. VARIETIES AFFECTED

As already mentioned, the presence of leaf scald disease was first established in the early part of 1931 as occurring on the cane varieties Manoa 160, H 109, 1926 C 182 and Wailuku 12. Since that time the disease has been found on sixteen other cane varieties, namely:

Manoa 31, 96, 160, 185, 186 and 195.
Yellow Tip.
Striped Tip.
H 335.
Kohala 73, 107 and 202.
1926 C 187.
1927 C 350.
U. D. 1.

Of these varieties, Yellow Tip, Striped Tip, Manoa 160, 185, 186 and 195 and Kohala 107 and 202, have proved to be the most susceptible. On the others the disease is thus far sporadic. In certain instances, the symptoms appearing on several of the above-named varieties were atypical, for example, on the variety Kohala 202 at Hakalau. In such cases *B. albilineans* was isolated and identified before a positive diagnosis was completed.

With the exception of H 109, U. D. 1, Yellow Tip, Striped Tip and Kohala 107 the remaining cane varieties listed above are still in experimental tests regarding their merits as commercial cane varieties. At present both Yellow Tip and Striped Tip canes are being rapidly replaced by canes of superior agricultural qualities which incidentally are much more resistant to leaf scald disease. The disease has not been observed on the following commercial varieties: Yellow Caledonia, D 1135, P. O. J. 36, 213, 2878 and Badila.

The disease has been observed in two instances on H 109 cane, the variety most widely grown on the irrigated plantations. Two affected stools at Oahu Sugar Company, Ltd., on the island of Oahu, and a test plot at Onomea Sugar Company, on the island of Hawaii. In the former case cuttings of H 109, obtained from the latter plot at Onomea, were planted. The plot of H 109 cane at Oahu Sugar Company, Ltd., wherein two leaf scald diseased stools were found, together with a certain amount of adjoining cane of the same variety and of H 456 was immediately destroyed by the management. The area in which the H 109 cane was destroyed was left fallow for five months and then planted to the susceptible variety Manoa 160. The object of planting this variety was to determine if, perchance, as a result of soil infection, the disease might develop. Monthly inspections were made of this area of Manoa 160 and during ten months no symptoms of leaf scald disease were noted. There is reason to believe that the disease was completely eradicated and does not now exist on the island of Oahu.

No systematic experimental tests of the commercial and more promising new varieties have been conducted to determine the degree of susceptibility. Such tests are being considered in order that information may be available should the disease become epidemic.

As a result of field observations and experimental tests Wilbrink (*loc. cit.*) has listed a number of the Java cane varieties in relation to their sensitiveness to the disease as follows:

Very Sensitive	Sensitive	Slightly Sensitive
E. K. 2	E. K. 28	Fiji
Brown 100	D. I. 52	P. K. I.
Black Borneo	S. W. 3	B. 247
Yellow Batjan	P. O. J. 826	Kassoer
B. 221	F. 90	
B. 36	Tjepiring 24	
P. O. J. 312	Black Cheribon	
P. O. J. 979	Chunnee	
P. O. J. 100	Loethers	

North (*22*, p. 15) published a list of a number of the Australian cane varieties in which they are arranged in order of their degree of susceptibility to leaf scald, as follows:

Susceptible	Moderately Resistant	Susceptible but Tolerant	Highly Resistant
Mahona	Nanemo	Badila	Malabar
H. Q. 243	Oramboo		N. G. 14
7. R. 96	Korpi		Innes 131
8. R. 31	(Clark's Seedling H. Q. 426)		D 1135
H. Q. 114	Pompey (7. R. 428)		H 109
	Goru and Sports		H. Q. 5
	(N. G. 24, 24A, 24B)		H. Q. 409
	N. G. 16		Q. 813
	M. 1900 Seedling		

Shepherd (25) during a recent visit to Australia and Java commented on the degree of resistance of certain varieties to gumming disease and leaf scald disease in these two countries. Shepherd comments as follows on the behavior of certain varieties in relation to leaf scald:

White Tanna (known as Malabar in Australia)—Moderately susceptible and tolerant to leaf scald, apparently more so than it is in Mauritius. . . . .

Black Innes apparently identical with M. 131—seems immune to leaf scald.

R. P. 6—Very resistant to "scald."

D. 1135—Highly resistant to "scald."

P. O. J. 2878—Moderately susceptible to "scald." Degree of susceptibility warranting the application of control measures in Java. . . . . .

B. H. 10/12—Apparently reacts to "scald."

Badila—Moderately susceptible but highly tolerant to "scald." It seems to possess a higher degree of tolerance to the disease than does White Tanna. Under the tropical conditions of Northern Queensland its tolerance seems less than in the subtropical districts of Northern New South Wales.

P. O. J. 2714—No information is available as to its behavior to "scald."

S. C. 12/4—No information is available as to its behavior to "scald."

Q. 813—It is highly resistant to "scald" and other diseases, in addition to gumming.

The following list of commercial cane varieties grown in Queensland has been prepared by Bell. The varieties are segregated according to their resistance to the disease:

Highly Resistant	Resistant	Moderately Susceptible	Susceptible But Tolerant	Susceptible	Very Susceptible
D 1135	M. 1900	P. O. J. 2878	Badila	H. Q. 426	E. K. 28
M 189 (Black Innes)	H 109	P. O. J. 2714	S. J. 4	Goru	
Uba		Pompey			
Q. 813		Oramboo			
H. Q. 409		Nanemo			
		Korpi			

IX. ECONOMIC IMPORTANCE

North (21) points out that the greatest economic losses in Australia were in connection with the variety Mahona, which proved extremely susceptible to leaf scald. In several districts the culture of Mahona, a very high sucrose cane, had to be abandoned.

The greatest losses occur from attacks of leaf scald disease when entire stools are killed outright. There is not only a reduction in cane and sugar yields but additional costs are incurred in replanting the blank spaces should the epidemic be sufficiently severe to kill out large numbers of stools. The degree of infection and severity of the disease depends upon the susceptibility of the cane variety grown and in some measure on the climatic conditions.

According to Bell, definite losses in Queensland have occurred on Badila cane under somewhat unfavorable growing conditions, but the major losses in recent years have occurred in H. Q. 426, which is an early maturing variety. So far a suitable variety has not been found to replace H. Q. 426. Several very promising commercial seedlings, such as S. J. 7 (South Johnstone), proved susceptible to leaf scald and were discarded. In Java, Wilbrink stated that the disease often causes severe damage in young plant fields and that it was not possible to grow certain varieties having high sugar-yielding qualities because of their susceptibility to the disease. She also pointed out that the sugar yields have been reduced in those fields where the disease was epidemic. The losses in Formosa from the disease in the commercial fields have been negligible, according to Miyake. Economic losses in other sugar-growing countries have been somewhat severe on susceptible varieties.

In Hawaii no commercial losses have resulted from the disease since it has been found in such limited areas. It has been recommended that very susceptible varieties, such as Manoa 160, 185, etc., be eliminated at the end of the crop cycle. Leaf scald is potentially of considerable economic importance and it is advisable that susceptible cane varieties be avoided unless their commercial superiority warrants the care necessary to prevent the development of the disease in large areas.

X. TRANSMISSION

Leaf scald, being a systemic disease, is transmitted chiefly by planting diseased cuttings and by knife infection. The transmission of the disease by cut-

tings has been repeatedly demonstrated in controlled experiments in Java and Australia. The occurrence of the disease in certain fields has been definitely associated with cuttings taken from affected fields. There are several authentic records showing that the disease has been carried from one country to another with cane cuttings. Bell and Cottrell-Dormer (4, p. 1) state:

Owing to the masking of symptoms under certain conditions, leaf scald is very difficult to detect, even in very susceptible varieties, and for this reason we expect that it will soon be found to have penetrated the quarantine defences of most countries. Moreover, one may very commonly find leaf markings which are very similar to those associated with leaf scald, but not positively identifiable except by recourse to cultural methods. To ensure reliable conclusions as to the presence or absence of the disease under these conditions it is obvious that there should be no doubt as to the suitability of the culture medium employed for isolation purposes, irrespective of heavy or light seeding.

North (22, pp. 30, 31) comments on the transmission of the disease as follows:

Use of Infected Planting Material.—This has undoubtedly been the chief means of dissemination. There can be little doubt that the disease was first brought to Australia and was then distributed far and wide in infected cuttings. That it was introduced to the Richmond from the Clarence in 1912 in cuttings of N. G. 16 is known. Growers have also propagated the disease on a large scale by using cuttings from infected fields for planting. Even those who are familiar with the disease are still propagating it in this manner, because it is impossible to select only healthy seed cane from an infected crop, even from a very slightly infected one. For many canes which are infected are of normal healthy appearance and devoid of any symptoms which betray their condition. And cuttings from these produce diseased stools of cane.

Both North (22) and Wilbrink (*loc. cit.*) have shown that the causal organism of leaf scald disease may easily be transmitted with cane knives. Cane cuttings for planting material were prepared from healthy stalks with a sterilized knife. These cuttings produced healthy plants. Cuttings were prepared also from healthy stalks of cane but were cut with a knife contaminated by cutting affected stalks. In almost every case the young shoots resulting from these cuttings manifested definite symptoms of leaf scald disease. The results of such a field test, conducted by Wilbrink, are shown in Fig. 13.

The subject of knife infection has been summarized by North (22, p. 40) and a portion of his summary follows:

In view of the wide use made of cane knives in ordinary farm practice, it seemed that knife infection might be one of the chief modes of dissemination. In harvesting crops for the factory, it would serve to transmit the disease from stool to stool in fields to be ratooned. The cane-cutters might also carry infection on their knives from one field to another. In harvesting seed cane and preparing cuttings for planting, not only would the ratoon crops be concerned, but the fields newly planted would be still more vitally affected. The seed cane would be liable to knife infection both while being harvested and while being cut up into cuttings.

Wilbrink recommends a 5 per cent solution of lysol in preference to mercuric bichloride (1-1000) for disinfection. The latter attacks the metal in the knives. It is also considered advisable in Java to add a red or blue color to the lysol solu-

tion so that the inspectors can easily see if the men who are preparing the cuttings are properly following instructions. Following this procedure the cut ends show red or blue stains when examined.

In Australia it has been suspected that the disease is also transmitted by means other than those above mentioned. These methods are now being studied, but at present no definite information is available.

The possibility of the organism being able to remain viable in the soil for any period of time has been investigated. From studies of this particular point it appears that there is little danger of the organism persisting in the soil and later infecting cane plants. If susceptible varieties are planted subsequent to the plowing of an area where the disease has occurred, experience indicates that the varieties will remain healthy. Infection might occur as a result of diseased volunteer stools developed from the old stubble. Therefore, should it be necessary to eliminate a variety on account of leaf scald infection, every effort should be made to destroy ratoons before replanting. All attempts to transmit the disease through the soil have been negative. Apparently *B. albilineans* is poorly adapted to a saprophytic mode of life and is incapable of persisting long in the absence of a susceptible host plant. No references to alternate hosts have been found in the literature.

XI. CONTROL MEASURES

The outstanding recommendations for the control of leaf scald disease are those prescribed by Wilbrink, North and Bell. A summary of the recommended procedures follows in the order of their importance:

1. The substitution of resistant varieties is no doubt the most effective method for controlling the disease under epidemic conditions. According to North no variety has been found immune to the disease but many have shown a high degree of resistance. He mentioned that the variety Mahona in Australia proved so susceptible to leaf scald that it was necessary to abandon its culture in many districts, even though it was a very satisfactory commercial cane. For information regarding the relative susceptibility of varieties see pages 189-191.

In Hawaii, the Tip canes and some of the Manoa seedlings, namely, Manoa 160, 185, 186 and 195 appear to be highly susceptible to the disease when compared with many of the other varieties growing under identical field conditions. P. O. J. 36, which is replacing the Tip canes in certain localities, has proved to be quite resistant to the disease.

2. The selection of healthy cuttings for planting material offers an excellent measure for reducing the spread of leaf scald. The disease is systemic and is chiefly transmitted with diseased cuttings. By making frequent inspections of a field it is possible to establish whether or not it is advisable to select planting material therefrom when the field is harvested. In Australia, it is recommended that no cuttings be selected within a radius of a quarter of a mile of a diseased stool.

3. The disinfection of cane knives has aided in reducing the spread of the disease. Both North and Wilbrink have demonstrated that leaf scald disease may be transmitted with the cane knife. (See page 192 and Fig. 13.) Healthy cuttings were cut with knives that were previously used for cutting diseased stalks, and a high percentage of the plants from these cuttings developed the disease. Plants from healthy cuttings which were cut with sterilized knives remained healthy.

4. All diseased plants should be rogued and destroyed as soon as they are observed in the field. The disease has been successfully controlled by this measure in several countries, especially in localities where attempts to control the disease have been made before it became too widespread.

5. To insure healthy planting material for fields, or experimental tests, nurseries are sometimes maintained in isolated districts. By frequent inspections and roguing diseased plants, the "seed" plots are kept free from the disease. By this practice it is possible to begin with entirely healthy planting material.

6. Another measure of control that offers considerable promise is to subject cuttings to the hot water treatment if there is any question regarding their condition. The cuttings are submerged in water at 52° C., for 20 minutes. Following this treatment they are immediately placed in cold water in order to quickly lower their temperature. It will be necessary to conduct further tests with our different varieties before the effectiveness of this treatment under local conditions can be determined.

XII. SUMMARY

Leaf scald disease of sugar cane was first recognized in the Hawaiian Islands in December, 1930, although there is evidence which indicates that this disease has been present sporadically for many years. The history of this disease in other countries shows that it is capable of causing serious economic losses where large areas of susceptible cane varieties have become infected.

The cause of leaf scald disease is a minute bacterium about 0.3 x 0.8 micron in size, named *Bacterium albilineans* Ashby. This bacterium was isolated, cultivated and identified many times in the course of these studies. Its relation to the disease was proved by inoculations of cane grown under carefully controlled conditions as well as in the field.

The characteristic symptoms of this disease, if present in their entirety, are amply sufficient for diagnosis. However, it is insidious in nature and according to authorities is capable of existing in masked form for protracted periods. Two phases of leaf scald are recognized: (a) The chronic phase, characterized by white leaf stripes, the copious development of etiolated "lalas" (side shoots) and suckers, and red discolorations of the vascular bundles in the nodes; (b) the acute phase with less definite symptoms, which terminates in sudden wilt of individual stalks, stools or entire fields.

The bacterial infection is transmitted chiefly by diseased cane cuttings and by cane knives. The latter, becoming infected in cutting a diseased stalk may infect

propagating material, or the stubble of cane being cut for seed. There is no evidence indicating that infection persists for long periods in the soil.

Procedures recommended for the control of leaf scald in Australia and Java emphasize the importance of sanitary precautions. Cuttings from healthy cane only are considered for planting and transmission by knife infection is prevented by the use of disinfecting solutions. Regarding the choice of cuttings for planting, experience in Australia has indicated that no cuttings should be taken from cane within one-half mile of any leaf scald diseased stool.

In Hawaii, leaf scald disease has thus far been almost entirely restricted to a few areas of locally bred varieties, on the islands of Hawaii and Kauai, with a limited sporadic occurrence elsewhere. No appreciable commercial loss has been experienced. However, the disease should be regarded as potentially important to our industry, since the outcome of exposing our fields of present and future commercial varieties to infection cannot be predicted with assurance. H 109 is reported to be susceptible to leaf scald in the Philippines and resistant in Australia, which might be construed to indicate inherent susceptibility of this variety, varying in degree with the climate. While the sporadic occurrence of this disease in Hawaii for a number of years indicates it to be a factor of minor commercial importance it may indicate a lack of opportunity to become epidemic.

In conclusion the authors wish to express their sincere thanks to the managers and other members of the personnel of the plantations and to members of the Experiment Station staff for the active cooperation extended to them during the progress of these studies.

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A Study of Correlation Between the Cane Yields and Quality Ratio of Irrigated Cane

By Ralph J. Borden

General opinion prevails amongst our sugar men that poor juices are ordinarily associated with high cane yields, and conversely that with lower cane yields, we are apt to have better juices. We have, however, noted numerous exceptions to this generalization and have seen excellent juices from high cane yields as well as very poor juices from yields that were less than average ones.

The relationship of these two factors has been studied by subjecting the individual plot data from all field experiments that have been conducted at Waialua Agricultural Company and the Waipio substation on the crops from 1926 to 1931, inclusive, to a correlation study. The results which are offered in the accompanying table may be best interpreted in conjunction with the following table which has been adapted from Fisher and shows the amount of correlation (r) which is needed for significance when different numbers of items are being compared.

Actual No. of Items	Amount of Correlation (r) Needed for Significance	Actual No. of Items	Amount of Correlation (r) Needed for Significance
3	.997	11	.60
4	.95	12	.58
5	.88	13	.55
6	.81	14	.53
7	.75	15	.51
8	.71	18	.47
9	.67	20	.40
10	.63	44	.29
		100	.19

The tests have been segregated into similar groups, i.e., Amounts of Nitrogen, Amounts of Phosphate, etc., and the correlations for each treatment are tabulated thereafter. A total of 74 experiments is included, in which 227 correlations have been made. Only 36 of these show a correlation coefficient that is large enough to be considered definitely significant, and of these, 31 are significantly negative and 5 significantly positive. There is no question but that the predominance of negative signs in the column of r, indicates that the aforementioned opinion, which associates high yields with poor juices and lower yields with good juices, may be right. The fact, however, that fully one-third of the cases studied show positive signs, is also an indication that good juices may accompany the higher yields, or poor juices the low yields. Most of us know of instances of positive correlation between poor juices and low tonnage, particularly where a condition of over-ripe and dead cane is prevalent. In this study, we have noted that 102 of the 227 treatments represented, have one or more instances wherein an individual plot has a cane yield that is higher (by at least 2 tons) than its treatment average

and a quality ratio that is also better (by at least .2 ton) than the average. Thus, high tonnage cane, *per se,* does not necessarily mean poorer quality.

In the Amounts of Nitrogen group, we had thought that we might find a higher significance, as indicated by an increasingly greater amount of negative correlation, with the larger than with the smaller application of nitrogen in each test: somewhat as exemplified in Waipio T-1927, where a correlation of —.50, —.74, and —.97 is obtained for the 191-, 228- and 266-pound nitrogen treatments, respectively. As a matter of fact, we find more instances where the reverse is true, i. e., less significance or a lower amount of negative correlation with the highest than with the lowest nitrogen application. This is illustrated by Waialua 14AN-1929: for the plots receiving only 90 pounds of nitrogen, we have a significant negative correlation of —.82 whereas in the largest or 225-pound treatment, although such treatment resulted in an average gain of 20 tons of cane over the lower amount, the amount of negative correlation is —.61 and indicates less significance to any direct relationship between tonnage and quality ratio. Out of the 68 treatments represented in this group of nitrogen experiments, we find only nine that have a definitely poorer quality ratio associated with the higher plot yields of cane.

In the Amounts of Phosphate group, we find 3 out of 29 comparisons showing a definite negative correlation between T. C. A. and Q. R., and in the Amounts of Potash group, 4 out of 19, or only 20 per cent of the cases studied, show this relationship definitely. None of the groupings made show a greater percentage than this cited for potash, which is very small.

It would seem questionable whether the purposely introduced variables of these experiments, to which we are inclined to give credit for the yield differences involved, have in themselves had a definite effect on the quality ratio. We could cite many examples to show this lack of relationship, but one will suffice to show what we mean: In Waipio L1-1926, an NK plot which produced 72 tons of cane with a quality ratio of 8.3 is found adjacent to an NPK plot that yielded 80 tons with a quality ratio of 7.3; in another part of the same test, we have an NK plot giving 62 tons with a quality ratio of 8.0 that is next to an NPK plot credited with 67 tons of cane and a quality ratio of 9.9. Most certainly, the addition of P_2O_5 which we have reason to feel has increased the cane tonnage in both pairs of plots, cannot be credited with improving the quality ratio in one case and charged with spoiling it in the other, as these data indicate.

We find many instances within blocks of plots that have had the same treatment, where inconsistencies are evident. Thus, if the NPK plots of Waipio U-1927 are arranged in descending yield order and their respective quality ratios placed against such arrangement, we find it difficult to believe that the applied treatment is the cause of the variation in quality ratios observed. Similarly, if the quality ratios of the NP plots are arranged in order, and their respective tonnages placed against them, it is difficult to find any definite relationship between the tonnage and the quality ratio setup that might be a cause of the treatment that was imposed.

NPK Plots Arranged in Descending Order of Cane Yields	Respective Q. R.'s	NP Plots Arranged in Descending Order of Q. R.'s	Respective T. C. A.'
86 tons	9.4	8.1	68 tons
83 "	8.6	8.7	71 "
81 "	8.6	8.9	75 "
79 "	8.3	9.1	56 "
79 "	8.2	9.1	71 "
77 "	8.6	9.5	69 "
72 "	8.5		
71 "	8.6		
54 "	9.0		

These facts serve to point out that the condition under test in our experiments is not always primarily responsible for the result obtained. Inherent soil effects, human errors, and weather influences are plausible suggestions for many of the discrepancies noted. Most certainly do we have an indication that direct cause and effect relations between cane tonnage and quality ratio have not as yet been established.

CORRELATION BETWEEN T. C. A. AND Q. R. IN FIELD EXPERIMENTS FROM WAIPIO AND WAIALUA

AMOUNTS NITROGEN	Treatment	n	r
Waipio C 1930	A—150 lbs. N	8	—.64
	B—200 lbs. N	8	+.20
	C—250 lbs. N	8	—.20
Waipio C 1929	A—250 lbs. N	8	—.56
	B—300 lbs. N	8	—.50
	C—350 lbs. N	8	—.49
Waipio C 1927	A—192 lbs. N	8	—.90*
	B—230 lbs. N	8	—.58
	C—269 lbs. N	8	—.66
Waipio C 1926	A—275 lbs. N	9	—.28
	B—300 lbs. N	9	—.37
	C—325 lbs. N	8	—.46
Waipio J 1927	A—250 lbs. N	7	+.74*
	B—270 lbs. N	7	+.10
	C—300 lbs. N	6	—.01
	D—324 lbs. N	5	—.87*
Waipio T 1926	A—250 lbs. N	7	—.51
	B—275 lbs. N	8	—.58
	C—300 lbs. N	7	—.49
Waipio T 1927	A—191 lbs. N	8	—.50
	B—228 lbs. N	7	—.74*
	C—266 lbs. N	7	—.97*

* These correlations may be considered as definitely significant.

AMOUNTS NITROGEN	Treatment	n	r
Waialua 39 AN			
1931	A—200 lbs. N	8	—.52
	B—140 lbs. N	8	+.08
Waialua 36 AN			
1931	A— 70 lbs. N	9	—.45
	B—110 lbs. N	9	—.30
	C—150 lbs. N	9	—.43
Waialua 33 AN			
1931	A— 70 lbs. N	11	—.30
	B—110 lbs. N	12	+.07
	C—150 lbs. N	12	+.37
Waialua 3 AN			
1930	A—150 lbs. N	5	—.33
	B—200 lbs. N	5	+.55
	C—250 lbs. N	6	—.39
	D—300 lbs. N	6	—.09
Waialua 26 AN			
1930	A— 90 lbs. N	9	—.50
	B—125 lbs. N	8	—.75*
	C—160 lbs. N	9	—.28
Waialua 15 AN			
1929	90 lbs. N	6	+.17
	145 lbs. N	6	—.30
	200 lbs. N	6	—.06
	255 lbs. N	6	+.53
Waialua 18 AN			
1929	90 lbs. N	6	—.93*
	150 lbs. N	6	—.54
	210 lbs. N	6	—.94*
	270 lbs. N	6	+.19
Waialua 19 AN			
1929	150 lbs. N	5	—.40
	210 lbs. N	5	—.82
	270 lbs. N	5	+.32
Waialua 13 AN			
1929	90 lbs. N	6	—.45
	145 lbs. N	6	+.02
	200 lbs. N	6	—.90*
	255 lbs. N	6	+.10
Waialua 14 AN			
1929	90 lbs. N	6	—.82*
	145 lbs. N	6	—.32
	200 lbs. N	6	—.41
	255 lbs. N	6	—.61
Waialua 6 AN			
1929	90 lbs. N	6	0
	150 lbs. N	6	0
	210 lbs. N	6	—.59
	270 lbs. N	6	+.14
Waialua 2 AN			
1928	150 lbs. N	4	—.16
	200 lbs. N	4	—.30
	250 lbs. N	4	—.43
	300 lbs. N	4	—.89

* These correlations may be considered as definitely significant.

	Treatment	n	r
Waialua 3 AN			
1928	150 lbs. N	4	+.59
	200 lbs. N	5	+.92*
	250 lbs. N	6	—.01
	300 lbs. N	6	—.22
AMOUNTS PHOSPHATE			
Waialua 32 AP			
1931	A—No P_2O_5	10	—.46
	B— 70 lbs. P_2O_5	10	—.16
	C—140 lbs. P_2O_5	10	—.49
Waialua 30 AP			
1931	A—No P_2O_5	9	—.11
	B—100 lbs. P_2O_5	9	—.48
	C—200 lbs. P_2O_5	9	—.56
	D—300 lbs. P_2O_5	9	—.64
Waialua 31 AP			
1931	E—No P_2O_5	9	+.15
	F—100 lbs. P_2O_5	9	—.45
	G—200 lbs. P_2O_5	9	—.51
	H—300 lbs. P_2O_5	9	—.48
Waialua 24 P			
1931	X— 70 lbs. P_2O_5	6	—.33
	A—111 lbs. P_2O_5	6	—.86*
	B—152 lbs. P_2O_5	6	—.008
	C—193 lbs. P_2O_5	6	+.20
Waialua 17 AP			
1931	A—No P_2O_5	6	—.57
	B—100 lbs. P_2O_5	6	—.04
	C—200 lbs. P_2O_5	6	—.52
Waialua 28 AP			
1930	A—No P_2O_5	9	—.27
	B—100 lbs. P_2O_5	10	—.42
	C—200 lbs. P_2O_5	10	—.52
	D—300 lbs. P_2O_5	9	—.22
Waialua 17 AP			
1929	No P_2O_5	6	—.75
	100 lbs. P_2O_5	6	—.47
	200 lbs. P_2O_5	6	—.70
Waialua 5 AP			
1929	70 lbs. P_2O_5	5	—.94*
	98 lbs. P_2O_5	5	—.60
	126 lbs. P_2O_5	5	—.08
	154 lbs. P_2O_5	5	—.88*
AMOUNTS POTASH			
Waialua 10 AK			
1931	A—No K_2O	6	—.54
	B—150 lbs. K_2O	6	—.68
	C—300 lbs. K_2O	6	—.84*
Waialua 29 K			
1931	A—No K_2O	7	—.69
	B—150 lbs. K_2O	7	—.84*
	C—300 lbs. K_2O	7	—.57

* These correlations may be considered as definitely significant.

AMOUNTS POTASH	Treatment	n	r
Waialua 10 AK			
1929	No K_2O	6	—.20
	100 lbs. K_2O	6	—.50
	200 lbs. K_2O	6	—.84*
Waialua 8 K			
1929	No K_2O	6	—.55
	100 lbs. K_2O	6	—.84*
	200 lbs. K_2O	6	—.70
Waialua 9 AK			
1929	No K_2O	7	—.24
	100 lbs. K_2O	7	—.69
	200 lbs. K_2O	7	—.70
Waialua 7 AK			
1927	No K_2O	2	—1.0 *
	100 lbs. K_2O	3	+.32
	200 lbs. K_2O	3	+.94
	300 lbs. K_2O	3	+.77
PLANT FOOD TESTS			
Waipio L1			
1926	N	14	—.12
	NP	15	—.27
	NK	13	—.39
	NPK	12	+.06
Waipio L1			
1928	N	11	—.58
	NP	11	—.82*
	NK	9	—.61
	NPK	8	—.55
Waipio U			
1927	NP	6	+.12
	NPK	9	+.08
Waipio V			
Using averages for	N	7	+.30
7 different years	NP	7	+.08
	NK	7	+.56
	NPK	7	+.40
Waialua 12 NPK			
1931	N	6	—.27
	NP	6	—.57
	NK	6	—.67
	NPK	6	—.91*
Waialua 11 PK			
1929	N	6	—.04
	NP	6	—.47
	NK	6	—.85*
	NPK	6	—.40
Waialua 27 HG			
1930	N only 160 lbs.	9	+.43
	HG 160 lbs.+70+70	9	+.05
Waialua 23 PK			
1930	A—N only	5	—.42
	B—NPK	5	—.52
	C—NPK	5	—.21

* These correlations may be considered as definitely significant.

PLANT FOOD TESTS	Treatment	n	r
Waialua 16 AHG			
1930	A—140-70-70	5	+.70
	B—190-140-140	5	—.33
Waialua 12 PK			
1929	N	6	—.45
	NP	6	+.76
	NK	6	+.82*
	NPK	6	—.33
Waialua 6 PK			
1927	N	6	—.33
	NP	6	+.20
	NK	6	—.85*
	NPK	6	—.64
FORMS OF NITROGEN			
Waipio D			
1930	NS	6	—.58
	AS	6	+.90*
	NL	6	—.39
	NS+AS	6	+.44
Waipio D			
1929	NS	6	—.78
	AS	6	—.49
	NL	6	—.73
	NS+AS	6	—.26
Waipio D			
1927	NS	6	—.10
	AS	6	+.05
	NL	6	+.11
	NS+AS	6	—.50
Waipio D			
1926	NS	6	—.74
	AS	6	—.50
	NL	5	—.64
	NS+AS	5	—.95*
Waipio L2			
1926	NS	4	+.66
	NL	4	—.20
Waipio L2			
1931	NS	4	—.80
	NL	4	—.65
Waipio R			
1930	NS	13	—.09
	Leuna	13	—.24
	Calurea	12	—.31
VARIETY TESTS			
Waipio A			
1927	H 109 checks	44	+.03
Waipio K			
1930	First 100 plots of H 109 in Variety test	100	—.10
Waipio L3			
1931	All H 109 check plots	17	+.42

* These correlations may be considered as definitely significant.

VARIETY TESTS	Treatment	n	r
Waipio S 1929	H 109 check plots	9	—.39
	H 109 ratoon	9	—.54
Waipio S 1930	Check plots of H 109 plant	4	—.07
Waialua 25 V 1931	H 109	8	—.74*
	H 8965	8	+.13
Waialua 35 V 1930	Waialua 4	4	+.04
	H 109	4	—.31
Waialua 34 V 1931	H 109	6	+.32
	H 8994	6	—.70
Waialua 22 V 1930	D 1135	4	—.47
	K 107	4	+.04
	K 202	4	+.88
	H 8965	4	+.03
	POJ 36	4	+.94*
	H 109	20	+.16
MISCELLANEOUS			
Waipio B 1926	A—N ½+½	8	—.49
	B—N ¼+½+¼	8	—.91*
	C—N ⅓+⅓+⅓	7	—.39
Waipio B 1927	A—N in 3 doses	12	—.61
	B—N in 2 doses	12	+.17
Waipio B 1929	A—N in 4 doses	10	—.28
	B—N in 2 doses	10	—.53
Waipio B 1930	A—N in 3 doses	12	+.07
	B—N in 1 dose	12	+.35
Waipio K 1927	A—Early N	5	—.81
	X—Later N	5	+.41
Waialua 20 T 1930	A—200 lbs. N ¼+¾	6	—.85*
	B—200 lbs. N ¾+¼	6	—.97*
	C—200 lbs. N ½+½	5	—.69
Waipio F 1930	Residual molasses—10 tons	5	—.74
	Check	5	+.23
Waipio F 1928	Seed	18	—.37
Waipio J 1930	A—Conc. Fert.	11	—.67*
	B—Old materials	11	—.78*
Waipio L1 1931	Fertilizer with seed	13	+.01
	No fertilizer with seed	13	+.03

* These correlations may be considered as definitely significant.

MISCELLANEOUS	Treatment	n	r
Waipio P			
1929	A—Irrig. 1 line	5	—.11
	B—Irrig. 2 lines	4	—.25
	C—Irrig. 4 lines	4	+.68
Waipio P			
1930	A } Same as 1929	5	+.37
	B } Same as 1929	4	—.43
	C } Same as 1929	4	—.40
Waipio T			
1930	CK—AS	4	—.85
	P_2O_5—AS	4	—.80
	Mud—AS	4	—.72
	CK—NS	4	—.97*
	P_2O_5—NS	4	—.71
	Mud—NS	4	—.95*

* These correlations may be considered as definitely significant.

Dwarf Disease of Sugar Cane*

By Arthur F. Bell
Pathologist, Bureau of Sugar Experiment Stations

Dwarf disease is the name which has been adopted for an apparently new and serious disease of sugar cane recently discovered in the Mackay district. Should this disease become widespread it would undoubtedly prove very destructive to certain varieties of cane, and this article has been written for the purpose of describing the symptoms of the disease and setting forth the situation for the benefit of cane growers.

History and Distribution

In 1930, Mr. A. P. Gibson reported that, as the result of a request received from a farmer, he and Messrs. Keogh and Osborn, of the Mackay Sugar Experiment Station, had inspected a field of plant P. O. J. 2714 and there found some 60 to 70 stools of cane affected with a disease with which they were not familiar. He further stated that in general appearance diseased plants resembled those infected with Fiji disease, but with the important distinction that no leaf galls were present. Two diseased stools were forwarded to this laboratory for examination and were received in good condition. Both consisted of dwarfed grass-like tufts, with yellowish streaked leaves, and greatly resembled extreme cases of Fiji disease, except that no leaf galls were present; they were also suggestive of the "lemon grass" stage of sereh disease, but with the additional feature of numerous yellowish leaf streaks. In our opinion the disease could not be classified as any disease as yet recorded in Australia, nor, in spite of certain resemblances to sereh and streak diseases, did it appear to be identical with any sugar cane disease heretofore described in any other part of the world.

A subsequent inspection of the infected field confirmed the impression that we had to deal with a distinct disease, and a survey of the surrounding district was undertaken by Mr. Osborn, who was later joined by Mr. Wood. The result of the survey indicated that the outbreak was quite restricted in its incidence, and was mainly confined to the Rosella district. The presence of the disease was eventually established in fifteen fields distributed over nine farms, while a few doubtful stools were seen and destroyed on three other farms. The amount of infection per field varied from a single stool to a maximum of slightly less than .5 per cent. Regular inspections of these farms were continued and diseased stools rooted out, with the result that at the last two inspections the disease was found on four farms only.

With one exception (but see below) the only variety found to be infected on these inspections was P. O. J. 2714, and in this particular case five diseased stools

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of P. O. J. 213 were found, in addition to one stool of P. O. J. 2714. On this farm also four stunted stools of E. K. 28 were found and destroyed, but the observer was unable to state definitely that the disease was dwarf disease. In five of the nine definite cases of the disease the stocks of P. O. J. 2714 had been obtained from the farm on which the outbreak was first discovered, but the remaining farms had had no interchange of varieties. On one of these three, cuttings of P. O. J. 2714 were received and planted in 1927, and all available supplies from the original stock were planted in 1928 and again in 1929; no disease was noticed until 1931, when one diseased stool was found in the ratoons of the 1929 plant, and approximately thirty stools in the 1930 late plant. The owner of the farm on which the disease was originally found received three sticks of P. O. J. 2714 in 1927; these gave rise to well-grown stools, which in 1928 were harvested and planted out in three rows. This cane was used in 1929 to plant two small blocks, one of which remained healthy, but in the other the 60 to 70 diseased stools mentioned above were found in 1930. An examination of the ratoons of the three rows from which these plants were taken revealed the presence of three diseased stools. Of these stools two were adjacent stools in one row, while the third was immediately opposite in the next row.

From the point of view of varietal susceptibility it is important to note that this particular farmer reported that early in 1931 he dug out a number of similarly diseased stools of H. Q. 426 (Clark's Seedling) in a field adjoining diseased P. O. J. 2714. This field was inspected on the occasion of the next visit, but no further infected stools were found. No definite observations on varietal resistance have been possible, but Q. 813 grown immediately adjoining the worst-infected field of P. O. J. 2714 has remained disease-free throughout.

Symptoms as Exhibited by the Variety P. O. J. 2714

The leaves, particularly the younger leaves, of diseased canes are marked with fine longitudinal yellowish stripes. The stripes are usually short, ½ to 2 inches long, but they may often be as much as 6 inches in length; they follow the direction of the veins and are about 1/16 inch wide, but may run together to give moderately wide bands, especially at the margin of the leaves. These markings are always more pronounced at the base of the leaves, and are not evenly distributed over the leaf surface as a rule. A good idea of the appearance of these leaf symptoms may be obtained by reference to Plates 2 and 3.

The leaves of diseased canes are stiff and erect, thus imparting a fan-like appearance to the cane top; the spindle and the younger leaves are usually twisted and deformed, of a lighter color, and shorter than normal (Plate 4). As in the case of mosaic, there is a progressive masking of the streaks in passing to the older leaves, but with dwarf disease the older leaves are of a darker green than normal.

The most striking symptom is seen in the case of primary infection. Here the stool consists of a number of stunted shoots which form no cane; the leaves are erect, stunted, and clustered, and bear the typical yellowish streaks with, as a rule, scalded or reddish tips, margins, or stripes, and later becoming frayed and torn.

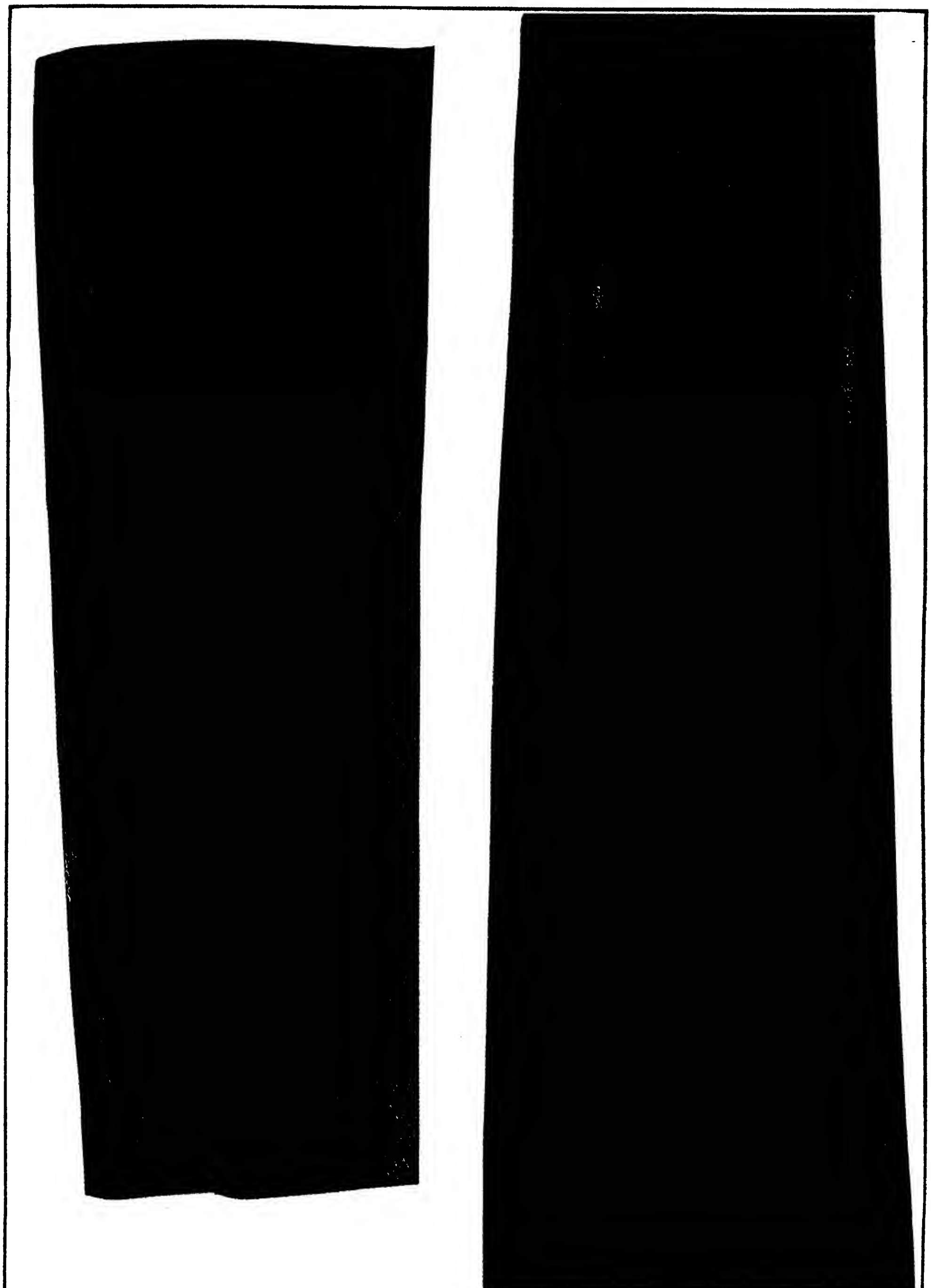

PLATE 2.

Leaves of diseased P. O. J. 2714, photographed by transmitted light. Streaks on left-hand leaf more closely resemble those of streak disease than is usually the case. Note uneven distribution of streaks in right-hand leaf and presence of yellowish marginal band on both leaves.

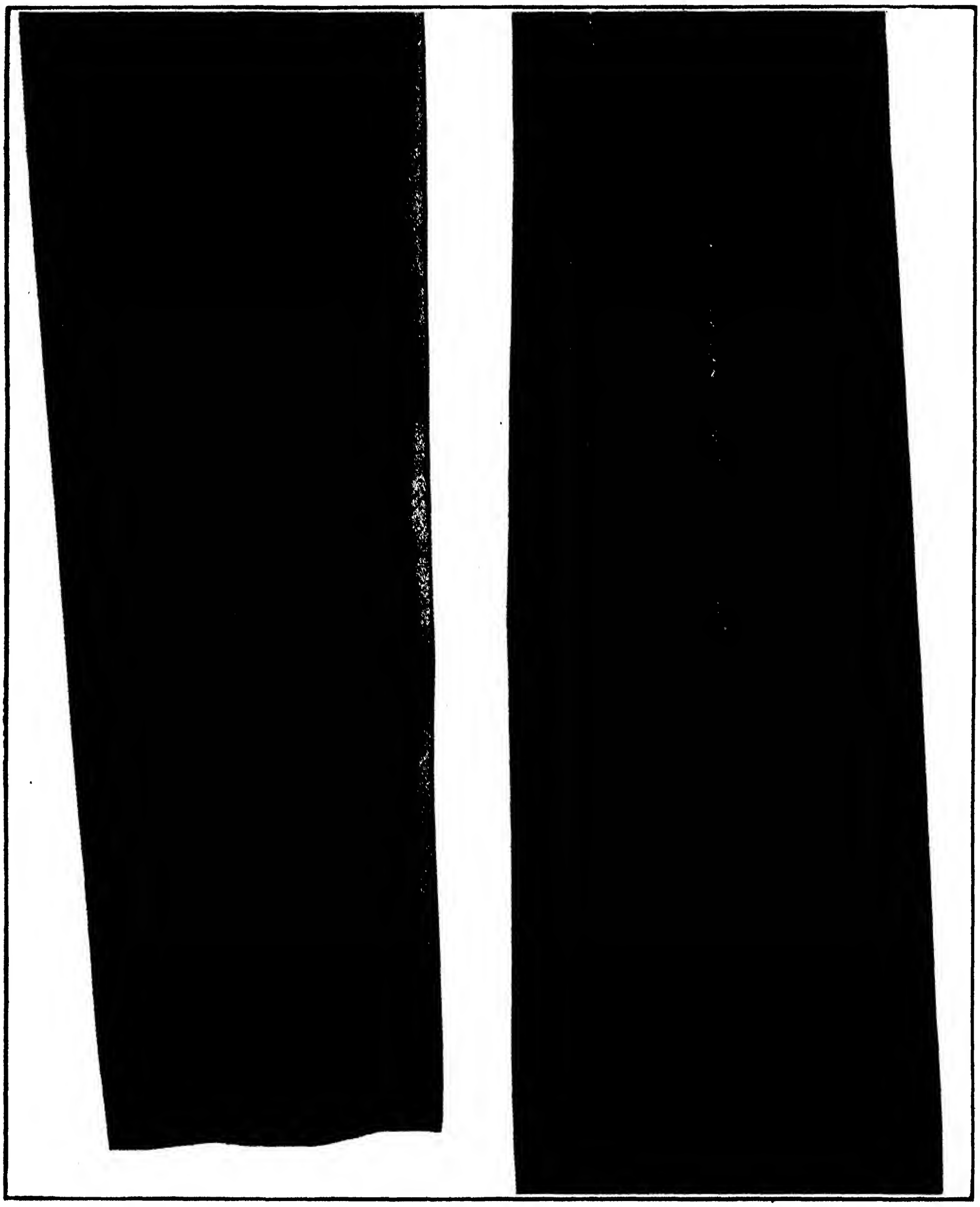

PLATE 3.
Similar to Plate 2 but photographed by reflected light.

PLATE 4.

Stalk of P. O. J. 2714, illustrating production of fan-like top following secondary infection.

The majority of the plants which we have produced by planting infected cuttings have died out without producing many shoots, but those which persist eventually produce a greater number of small shoots and resemble a tuft of grass. This stage of the disease much resembles extreme cases of sereh and Fiji diseases (Plate 5). Ratoon plants from diseased stools present a similar appearance and also form the grass-like cluster, with no production of cane. The life of such stunted shoots is usually very short.

In cases of apparently secondary infection, growth ceases suddenly and the top of the stalk tapers off to a point, forming the fan-like top. Such stunted stalks are soon outgrown by the healthy stalks in the same stool, and the upper internodes become sunken. The general appearance of such canes is again very similar to cases of secondary infection Fiji disease. There is no marked shooting at the eyes or production of aerial roots by the diseased stalks, nor is there any discoloration of vascular or storage tissue, nor, in fact, any macroscopic abnormality.

Histological Examination

A preliminary histological examination has failed to demonstrate the presence of any pathogenic organism within the tissues of diseased plants, but has revealed certain structural abnormalities which should form an interesting subject for subsequent examination. No definite abnormalities were observed in either stems or leaves of plants in which the infection was secondary, but a marked derangement of the tissues occurs in the vascular bundles of the leaves of the extremely stunted plants which result from primary infection. The derangement occurs to some extent in minor bundles, but is particularly associated with the major bundles, of which a typically distorted member is illustrated in Plates 7 and 8.

The bundle may be considerably enlarged, very irregular in shape, and frequently fused with an adjoining minor bundle. The chlorophyll-bearing sheath is incomplete, as a rule, and may be represented by a very few cells or be entirely absent in extreme cases. Within the bundle there is an abnormal development of comparatively thin-walled lignified cells which frequently radiate through the bundle in two or more strands, bringing about distortion and altering the relative positions of component tissues. Phloem may be almost entirely absent and confined to one of the resultant sectors, or may be found scattered in more than one sector or at the ends of the lignified strands. The walls of the cells of the lignified inner sheath surrounding the phloem appear thinner than is the case in normal cane, and the sheath is completely disrupted, but whether the strands of woody cells have their origin in this particular tissue has not been established. (See Plate 9.)

Relation to Other Diseases

The disease has features in common with Fiji, sereh, and streak diseases. The presence of the yellowish leaf streaks and the absence of galls on the under surface of the leaves—which are particularly prominent in Fiji-diseased P. O. J. 2714—ruled out the possibility of identity with this disease. Similarly the presence of these leaf streaks and the absence of any internal discoloration and adventitious

PLATE 5.
Typically stunted plant stool of P. O. J. 2714, 18 months old.

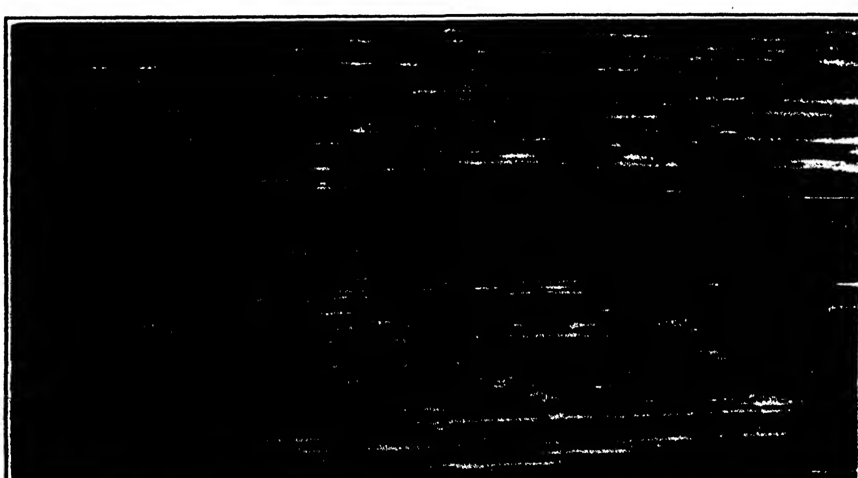

PLATE 6.
Streak disease in Uba. Compare with Plates 2 and 3.

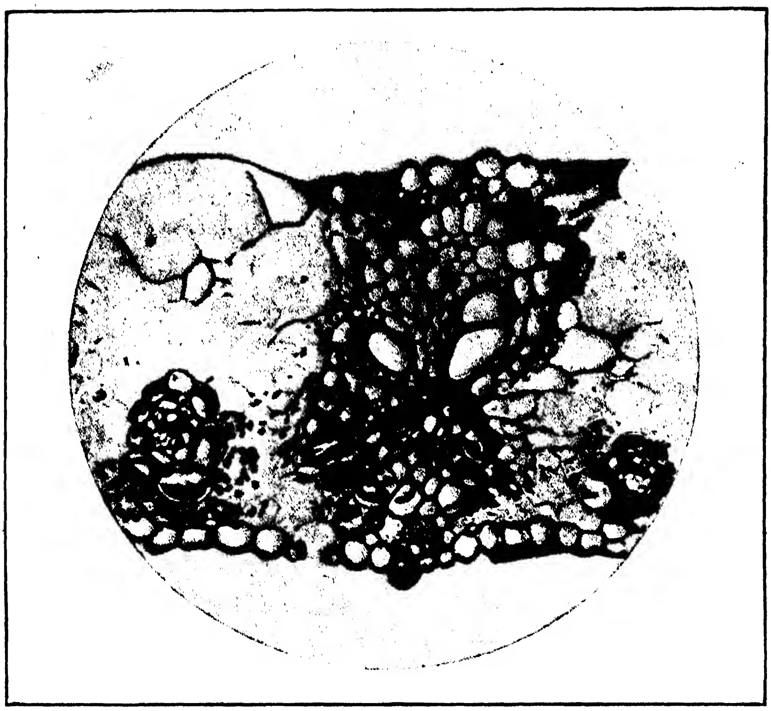

PLATE 7.

Cross section of major vascular bundle from leaf of P. O. J. 2714, showing abnormal development, presence of radiating strands of lignified tissue, and incomplete bundle sheath. *From a freehand section made and photographed by Mr. Cottrell-Dormer.*

root production strongly discounted the possibility of identity with sereh. In so far as streak disease was concerned, there appeared from the published report of Storey* to be considerable differences in color, length, and distribution of the leaf streaks, as well as the degree of stunting of diseased plants. Particular significance was attached to these differences in view of the statement by Storey (page 7) that "The symptoms of streak disease show a remarkable uniformity throughout all varieties of cane affected." At that time, however, P. O. J. 2714 did not appear to have been exposed to streak disease in South Africa, and thus it was possible that the variations in symptoms might be due to a difference in varietal response. Accordingly, photographs, preserved leaves, and a description of the external symptoms were forwarded to Dr. H. H. Storey of the Amani Institute, and Mr. A. P. D. McClean of the Natal Herbarium, and their opinion sought as to the identity of the disease. Both these gentlemen have expressed themselves as definitely of the opinion that dwarf disease is distinct from streak, although the leaf markings may bear a close resemblance at times. Dr. Storey directed attention to the following important differences between the two diseases:

1. The stiff fan-like top occurs only in young streak-diseased Uba, and in later growth diseased plants are not noticeably different in habit from healthy plants.
2. The stripes of streak disease are white rather than yellow.
3. They are usually only a few millimetres long and rarely more than an inch in length.
4. The leaf markings are evenly distributed over the leaf in the case of streak.
5. There is no deformity of the inner leaves, and older leaves do not assume a darker green than normal.
6. There is no masking of streak symptoms in older leaves.
7. Such abnormally severe stunting has not been observed with streak, nor do shoots die prematurely.
8. Secondary infection causes no sudden cessation of growth.
9. Shrinking of internodes has not been noted.
10. Ratoons grow normally after an initial stunted stage.

Mr. McClean expressed similar views, and also stated that he has observed no case of streak disease in P. O. J. 2714, although this variety is now being grown in districts where 100 per cent infection with streak may commonly be expected in susceptible varieties such as Uba.

In January, 1931, we were favored with a visit from Mr. E. F. S. Shepherd, Botanist in the Department of Agriculture, Mauritius. After inspecting diseased plants Mr. Shepherd furnished us with a report in which he made, inter alia, the following remarks:

"The streaks of dwarf disease are, however, in my opinion, usually longer than those encountered in streak disease and are not so uniformly distributed over the surfaces of affected leaves. The streaks of streak disease do not tend to fuse laterally to the same

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*** Storey, H. H. "Streak Disease of Sugar Cane." Union of South Africa, Department of Agriculture, Science Bulletin, No. 39, 1925.**

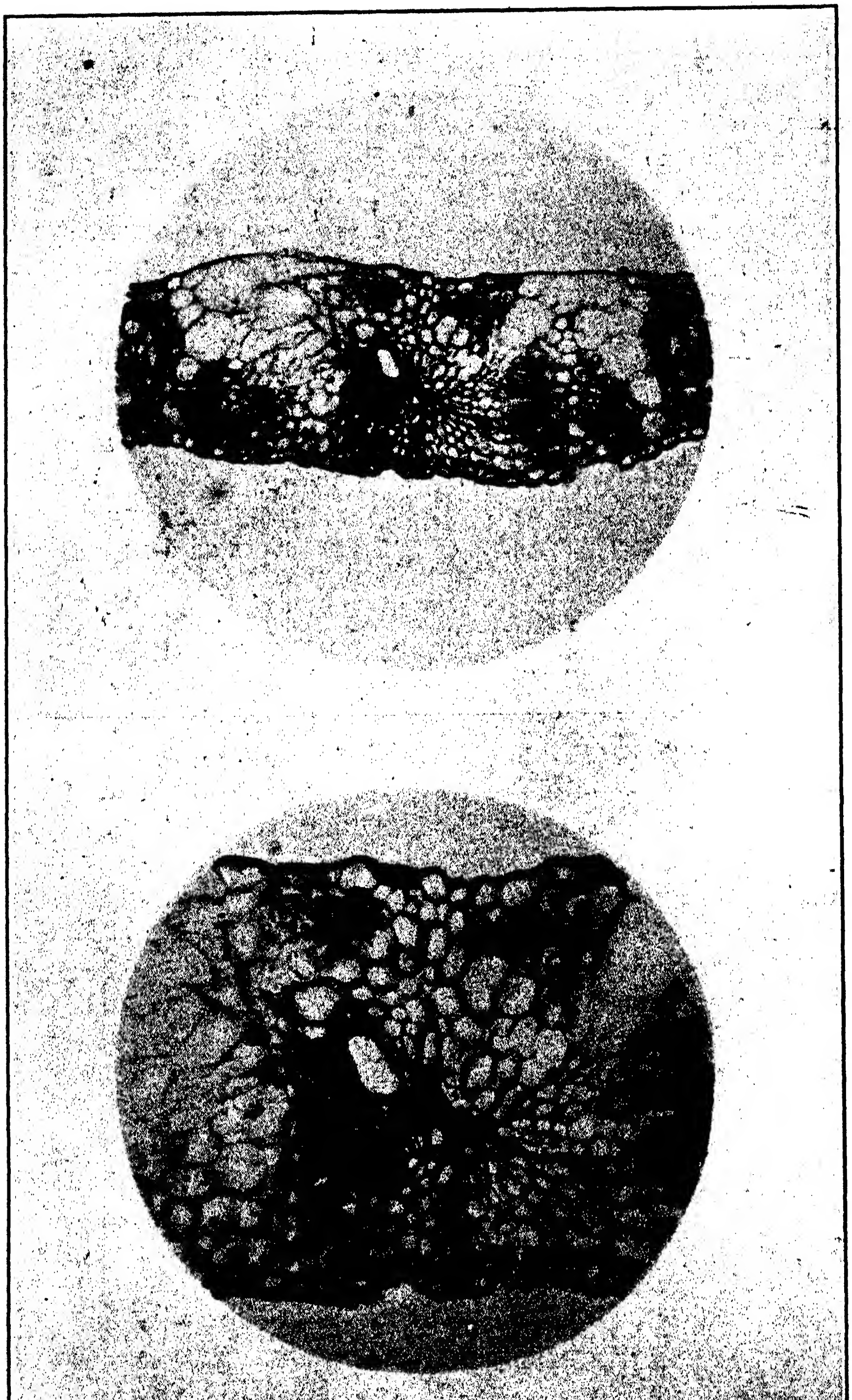

PLATE 8.

Transverse sections of leaves of P. O. J. 2714 affected with dwarf disease similar to that shown in Plate 7. The lower figure (x190) is an enlargement of a portion of the upper figure (x95). Preparations by W. Cottrell-Dormer. Photomicrographs by D. M. Weller.

Figures shown in Plates 8 and 9 are from slides furnished by Arthur F. Bell, January, 1932.

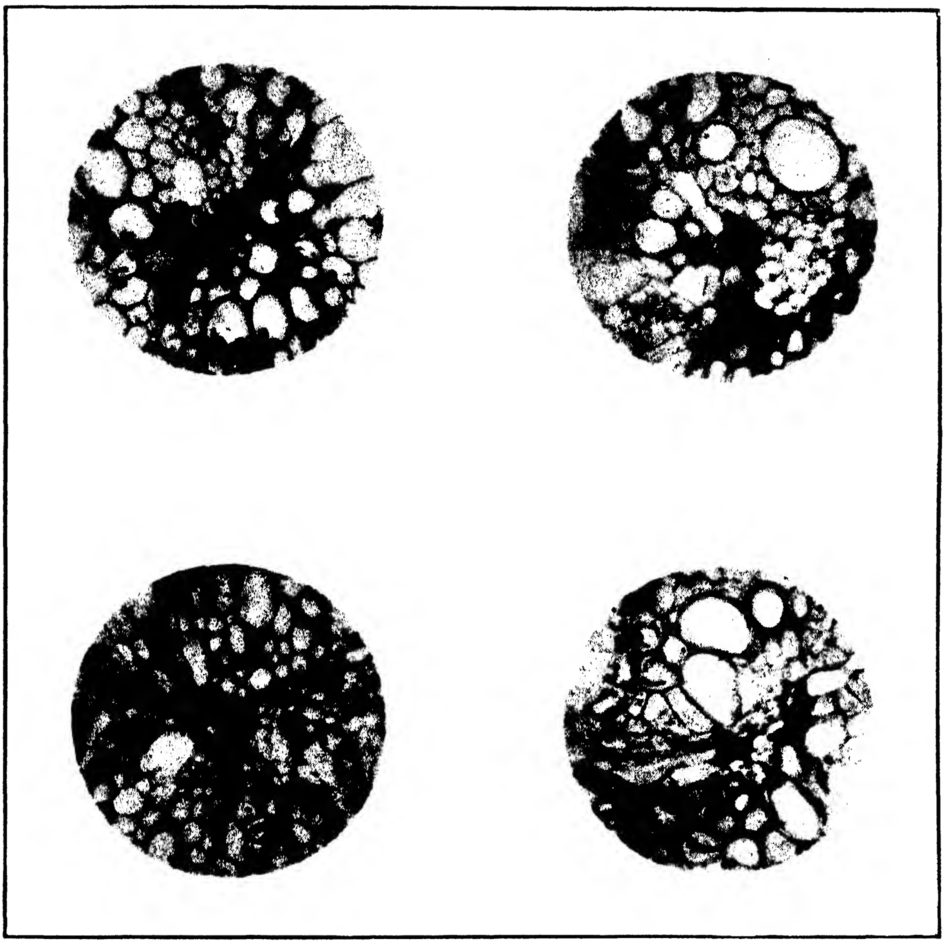

PLATE 9.

Transverse sections of major bundles of leaves of P. O. J. 2714 affected with dwarf disease (x250). The cause of the disease apparently prevented the complete differentiation of the tissues of the bundles and resulted in abnormal bundles composed chiefly of lignified tissues. Preparations by W. Cottrell-Dormer. Photomicrographs by D. M. Weller.

extent as do those of dwarf disease. The broad chlorotic bands towards the edges of leaves of dwarf disease affected canes do not, to my knowledge, occur in cases of streak disease, nor is there such a severe stunting of the shoots. Streak disease does not, to my knowledge, result in the death of shoots, which seems to be a constant character of dwarf disease. Dwarf disease has undoubtedly all the characteristics of a virus affection, but I am of the opinion that it is different from streak disease.''

Nature and Origin of the Disease

The origin and cause of this disease are, as yet, matters for speculation only. It certainly has all the external appearance of being a disease of the virus degeneration disease type, and derangement of vascular tissue is frequently a concomitant of such diseases, but beyond this nothing definite can be said. In the preliminary examination in the field Mr. Wood was unable to find any associated organisms, but reported a necrosis of phloem tissue in the leaves of plants produced by the planting of diseased setts. In the laboratory a detailed histological examination has failed to demonstrate the presence of associated fungi or bacteria, nor have any attempts to isolate an organism been successful to date; but this phase of the work will be continued.

The presence of the disease cannot be correlated with any particular soil type, and planting of diseased cuttings under widely different conditions has always given rise to diseased plants, while parallel plantings of healthy cuttings have given rise to healthy plants in each case. So far the planting of cuttings from apparently healthy canes in diseased stools has also given rise to healthy plants. From the results obtained by planting infected setts it seems unlikely that there is any prolonged masking of symptoms in the case of primary infection; assuming this point of view to be correct, secondary spread has been observed in a number of fields. The rate of spread has been comparatively slow and similar to what would be expected in the case of mosaic disease in a susceptible variety under similar field conditions. The results of secondary spread were most obvious during March and April, which is also a point of similarity with the spread of mosaic. Attempts at mechanical transmission by the use of the pinprick method developed by Sein* for the transmission of mosaic disease have so far given negative results.

Investigational work has been hampered by the fact that the outbreak occurred 600 miles from the laboratory, and also that as far as practicable diseased stools have been uprooted as soon as discovered. Attempts to maintain suitable experimental material in Brisbane have not been very successful, owing to the failure to produce plants consisting of other than small tufts of yellowish dying leaves; and pressure of other work has prevented the investigation of possible insect spread by the resident entomologist.

Three cuttings of each of the varieties P. O. J. 2714 and P. O. J. 213 were introduced from Java in January, 1922, along with P. O. J. 36, P. O. J. 100, P. O. J. 213, S. W. 3, D. I. 52, and F. 90. These canes were planted in the nursery of the Bundaberg Experiment Station and were grown under close supervision for some years, but no disease other than gumming disease was ever observed. P. O. J.

*** Sein, Francisco. ''A New Mechanical Method for Artificially Transmitting Sugar Cane Mosaic.'' Journal, Department of Agric., Porto Rico, Vol. XIV, No. 2, p. 49, 1930**

2714 and P. O. J. 213 from this stock are still being grown in the Bundaberg district, but have at no time exhibited symptoms of dwarf disease. Cuttings of these canes were sent to the Mackay Station in 1924 and propagated until 1927, when the first distribution was made. During the period 1927-29 many thousands of cuttings were distributed from Mackay Station to farmers in all parts of the State. Of the hundreds of farms to which the cane was distributed dwarf disease appeared on only four, which were all situated in the same locality (the plants on the five other positive and two doubtful farms were obtained from one of these four). On one of these four farms the disease did not appear until the second planting (three contiguous stools), and on another not until the third planting (one stool); the disease is so striking in appearance that it does not appear probable that it would be missed in small plantings. On each of the remaining two farms only a single stool was found, but these were found in the first planting.

From a consideration of the above facts there does not appear to be any likelihood of the disease having been introduced in cuttings from Java, quite apart from the fact that such a disease has not been reported from Java or any other country. The origin of the disease therefore remains a mystery; of the possible explanations of its appearance the most feasible at present is that the disease has been present in wild plants or other cultivated plants, and has been transmitted to sugar cane following the growing of susceptible varieties. Such a possibility is, of course, by no means remote, and there are numerous instances of sugar cane becoming infected with mosaic disease in this manner. Against this, however, is the fact that in spite of careful searching no suspicious symptoms have been observed on adjacent grass and weeds, but in this connection it should be borne in mind that the extremely droughty conditions prevailing over the past two seasons have been distinctly unfavorable for this type of observation.

Control

From the rather limited field observations which it has been possible to make, this disease appears similar to mosaic and Fiji diseases in many respects, including the time and rate of spread. For this reason the methods which are so successfully used in the control of these diseases commend themselves for use in this instance. It is accordingly recommended that the following measures should be put into operation by growers:

1. Study the symptoms of the disease in order to be able to recognize it in the field.

2. Carefully inspect, or have an officer of the Bureau inspect, any field (especially in the case of P. O. J. 2714, P. O. J. 213, E. K. 28, and Clark's Seedling) which it is proposed to use as a source of plants, and reject this field entirely if even a single stool of dwarf disease is found.

3. Inspect young plant and ratoon cane regularly and uproot any diseased stools as soon as they are found.

4. Keep fields and headlands as clean as possible.

5. Avoid planting P. O. J. 2714 if other varieties will give satisfactory yields.
6. In any case of doubt as to the presence of the disease, refer the matter to the nearest officer of the Bureau of Sugar Experiment Stations.

[J. P. M.]

The Cane-Killing Weed*

By Arthur F. Bell, *Pathologist;* W. Cottrell-Dormer, *Assistant Pathologist*

Although the existence of *Striga* as a parasite of sugar cane in Queensland has been recorded for a number of years, no detailed descriptions or illustrations have been published, with the result that the appearance and effects of the weed are still unfamiliar to most sugar farmers and technical workers in this State. Consequently, the following notes have been compiled to supplement the excellent illustrations which were executed by Mr. I. W. Helmsing under the general supervision of Mr. Henry Tryon, late Entomologist and Vegetable Pathologist in the Department of Agriculture. We are indebted to Mr. Robert Veitch, Chief Entomologist in the Department of Agriculture, for his courtesy in making available the services of Mr. Helmsing for the preparation of these plates.

History and Distribution

These weeds are classified botanically within the genus *Striga* and are of particular interest, inasmuch as they are members of the comparatively small group of flowering plants which are parasitic upon other plants. They are fairly common throughout the tropics, occurring abundantly, according to Pearson(5), in Tropical Africa, Egypt, Madagascar, Arabia, Ceylon, India, Siam, Java, and China. The term "cane-killing weed" is a general term applied to the members of this genus which are found parasitic upon the roots of sugar cane in Queensland.

In South Africa one species (*Striga lutea* Lour.), commonly known as the witchweed, has been recognized as a serious parasite of the roots of maize for many years. The effects of the parasite are particularly severe if the maize is planted near the time of germination of the witchweed seeds, so that it becomes infected in the young seedling stage. The witchweed is also found as a parasite of sugar cane in Natal, but to a much less extent than on maize.

Striga as a root parasite of cane was reported from India in 1921(4), and was stated to have first been noticed in the Patiala State Territory about 1914. In 1920, reports were received of a new disease in the sugar cane fields of the "Bet" lands of the river Sutlej. Upon investigation it was found that the cane roots were being attacked by flowering parasites, of which two were observed—namely, *Striga densiflora* Benth. and *Striga euphrasioides* Benth. In the course of the investigation, it was found that the parasite disappeared when the fields were rotated to cotton, and that therefore partial control had been unconsciously practiced in the past.

This parasite is also found on sugar cane in Mauritius, and in 1928 *Striga hirsuta* was reported as causing considerable damage on one estate(6).

* Reprinted from the *Queensland Agricultural Journal*, Vol. XXXVI, pp. 463-473, 1931.

Specimens of *Striga* spp. were collected early in the botanical history of Queensland, and *S. hirsuta, S. parviflora,* and *S. curviflora* were included in an early catalogue of plants(2), at which time they appeared to be generally distributed over the State. The first record of these plants as parasites of cane appears to have been in 1916, when Tryon(7) briefly reported *S. parviflora* as attacking cane in the Degilbo district. In 1924, the weed was found independently by Cottrell-Dormer at Carmila(2). Since that time at least three varieties or species of the weed have been found in various parts of the Burdekin, Proserpine, Mackay, and Bundaberg districts.

We have, on several occasions, found the weeds associated with wild grasses, but in no case was any apparent stunting produced. They, therefore, are an example of indigenous parasites which have established a state of equilibrium with their hosts, but the state of equilibrium has now been disturbed by the introduction of a new cultivated host plant which has proved susceptible and allowed the parasites to gain the ascendency.

Appearance of the Disease

As a rule the areas of infection are roughly circular in shape, with a diameter of a few yards. The damage to the crop may range from an almost imperceptible stunting, in the case of very light infection, to the premature death of the cane. In a typical case the stools are markedly stunted, with small sparse tops and clinging trash. The stunted green leaves stand out stiffly from the crown and the more recently dead leaves tend to stand out at an angle rather than hang loosely. As a result, the leaf blades present an appearance similar to the spokes of a wheel. The older leaves hang stiffly down the stalk. In common with most root diseases, the symptoms produced in the cane by these parasites are not particularly definite. The clinging trash may be responsible for the shooting of the aerial roots, but even in the recently dead canes there are no visible symptoms such as reddened fibres, etc. The root system does not appear to be reduced to any appreciable extent.

During the summer months the small weeds may readily be found in clusters at or near the base of the stools, while in some cases they may be generally distributed in the interspaces also. If a stool and the associated weeds are dug up and the soil carefully washed away, the white roots of the parasite will readily be distinguished from the dark-brown roots of the cane. Both sets of roots are much intertwined, and on careful examination it will be seen that the roots of the parasite are attached to those of the cane by means of small cup-like swellings. The number of such attachments per weed may vary from one to many.

After the death of the weeds in the autumn a careful search may be necessary before the dried bluish black plants may be found.

Description of the Parasites

The following botanical description of the genus *Striga,* to which these weeds belong, is taken from Hooker(3):

"Usually scabrid herbs, discolored or black when dry. Leaves, lower opposite, upper alternate, linear, entire, rarely toothed, sometimes reduced to scales. Flowers axillary

or the upper in bracteate spikes often 2-bracteolate. Calyx tubular, strongly 5-15 ribbed, 5-toothed or -fid. Corolla-tube slender, abruptly incurved at or about the middle or top; limb spreading, 2-lipped, upper lip usually short notched or 2-fid; lower, the inner in bud, 3-fid. Stamens 4, didynamous, included; anthers 1-celled, vertical, dorsifixed, bases obtuse, connective sometimes mucronate. Style thickened above, stigma simple. Capsule subglobose or oblong, loculicidal; valves entire, septiferous, separating from the placentas. Seeds very numerous, ovoid or oblong, reticulated. Species about 18, in the hotter regions of the Old World.''

As stated above, at least three distinct weeds have been found parasitic on cane in Queensland, but owing to the rather ill-defined differences between some of the recorded species, and in the absence of type specimens, we have not attempted to identify them. The chief differences are in flower color and habit, viz.:

(a) Erect, flowers light-blue or lilac.
(b) Trailing on ground, flowers light-pink.
(c) Erect, flowers light-pink.

The general characteristics of the weeds may be studied in detail by references to Plates 119 to 124. The above-ground stems are green, circular at the base, but becoming quadrified higher up (Plate 120, figs. 2 and 3; Plate 121, fig. 4). The leaves are small, elongated, and green, the lower leaves being opposite and the upper alternate. Both stem and leaves become bluish black in color when dried. Flowering takes place freely during the late summer; the flowers are small, sessile, and borne in the form of long interrupted spikes. The seeds are borne in small cylindrical capsules (Plate 121, fig. 6) which split longitudinally and liberate their contents. The seeds are very small (about one thirty-second of an inch long), light, and are produced in extremely large numbers. The underground portions of the stem are white, fleshy, and branched, and bear whitish scale-like leaves (Plate 119, fig. 2); the roots are light-colored and much branched and the rootlets bear root hairs, although these are not present in large numbers.

The complete details of the life history of these parasites are not available, but, according to Pearson(5), it is essentially as follows: The seed falls upon the ground in late autumn or early winter and remains dormant until the early spring, when it germinates. The root of the young seedling grows out and produces small whitish spherical bodies, or haustoria; when the root comes in contact with a root of the host plant it becomes affixed thereto by these haustoria (Plate 119), which then send forth outgrowths which burst through the outer layers of the root and penetrate to the vascular system. On examination of a section cut through both root and haustorium the vascular bundles of the parasite may be traced through the haustorium and outgrowths into the vascular system of the cane root, thus forming a continuous vascular system between host and parasite. In the first few weeks of its existence the parasite does not appear above ground and the leaves remain whitish and rudimentary, but once the aerial stalks appear above ground their subsequent growth is rapid.

Since the leaves are green, it follows that this parasite must be able to carry on photosynthesis during the above-ground period of its existence, and the presence

of some root hairs would enable it to absorb a certain amount of water and plant foods from the soil as well as from the roots of the host plant. It must therefore be classed as a semi-parasite, at least during the later period of its existence. It is generally assumed (4 and 5) that the stunting of the cane plant is due to the loss of water and plant foods sustained by the host, but we have frequently seen cane stools 3 feet high killed by a small number of weeds, the total dry weight of which would not exceed that of one or two cane leaves. In a recent outbreak on the Burdekin, in which this condition was observed, the cane had been grown under regular irrigation and had suffered no check in growth. The remainder of the field yielded 45 tons per acre, for a one-year crop, while in a patch several yards in diameter the cane had been killed when about 3 feet high. We are therefore inclined to the view that the weed must elaborate some substance toxic to the cane plant.

Transmission and Control

The cane-killing weed is an annual and the whole plant dies after flowering and the production of seed. It is propagated by means of these seeds, which, being small and light, are easily carried by the wind and drainage and irrigation water.

Owing to their intimate association it follows that any practice, such as poisoning, which will kill the parasite is also likely to kill the cane. If the total area attacked is not large, every effort should be made to prevent the weeds from flowering and setting seed which will infect the next year's crop. This may be effected by chipping, but owing to the fact that the underground stems are constantly sending up fresh aerial shoots it is necessary to inspect frequently and chip when required. The seeds are sensitive to heat, and the burning of trash will assist in killing all seeds above or near the surface of the ground. Where the crop is heavily infected, it is recommended that it should be ploughed out and the ground rotated to legumes, which are not attacked. Under these conditions no fresh seed will be set in that season and few, if any, of the previous season's seed may be expected to survive.

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(J. P. M.)

Description of Plates

PLATE 119

Fig. 1.—Young seedlings attached to the roots of the host plant by means of small cup-shaped haustoria

Fig. 2.—Parasite during underground period of existence. Note white fleshy stems, rudimentary leaves, and light colored roots attached by means of haustoria to the dark sugar cane roots, x 2.

PLATE 120

Fig. 1.—Underground stem. Natural size.

Fig. 2.—Junction of underground and aerial stems; the latter is green, round, and bears elongated green leaves. Natural size.

Fig. 3.—Upper portion of aerial stem, the stem is now quadrifid and the leaves alternate. Natural size.

PLATE 121

Specimen from Bundaberg; habit erect, flowers light-pink.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3.—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Portion of upper stem showing quadrifid nature.

Fig. 5.—Seeds, x 17.

Fig. 6.—a. capsule, x 2; b. cross section of capsule, x 4; c. empty capsule after splitting longitudinally and liberating the seeds, x 4.

Fig. 7.—Flower, dissected to show arrangement of floral parts, x 3.

PLATE 122

Specimen from Mackay; habit erect, flowers light-blue.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Flower bud, x 2½.

Fig. 5.—Flower dissected to show arrangement of floral parts, x 3.

Fig. 6.—Seed, x 17.

PLATE 123

Specimen from Proserpine; habit erect, flowers light-blue.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3.—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Extremity of tooth of calyx. Enlarged.

Fig. 5.—Seed, x 17.

Fig. 6.—Flower dissected to show arrangement of floral parts.

PLATE 124

Specimen from Burdekin; habit trailing, flower light-pink.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, bract, and bracteoles, in situ, x 2.

Fig. 3.—Calyx, x 4.

Fig. 4.—a. bract; b. and c. bracteoles, x 4.

Fig. 5.—Arrangement of floral parts, x 2.

Fig. 6.—Protective appendages on margin of bract. Greatly magnified.

PLATE VII.

Photograph of typical young cane-killing weed shoots taken shortly after harvesting in a Proserpine cane field. The two-shilling piece indicates relative size. (Taken from reprint from *Queensland Agricultural Journal*, November, 1931.)

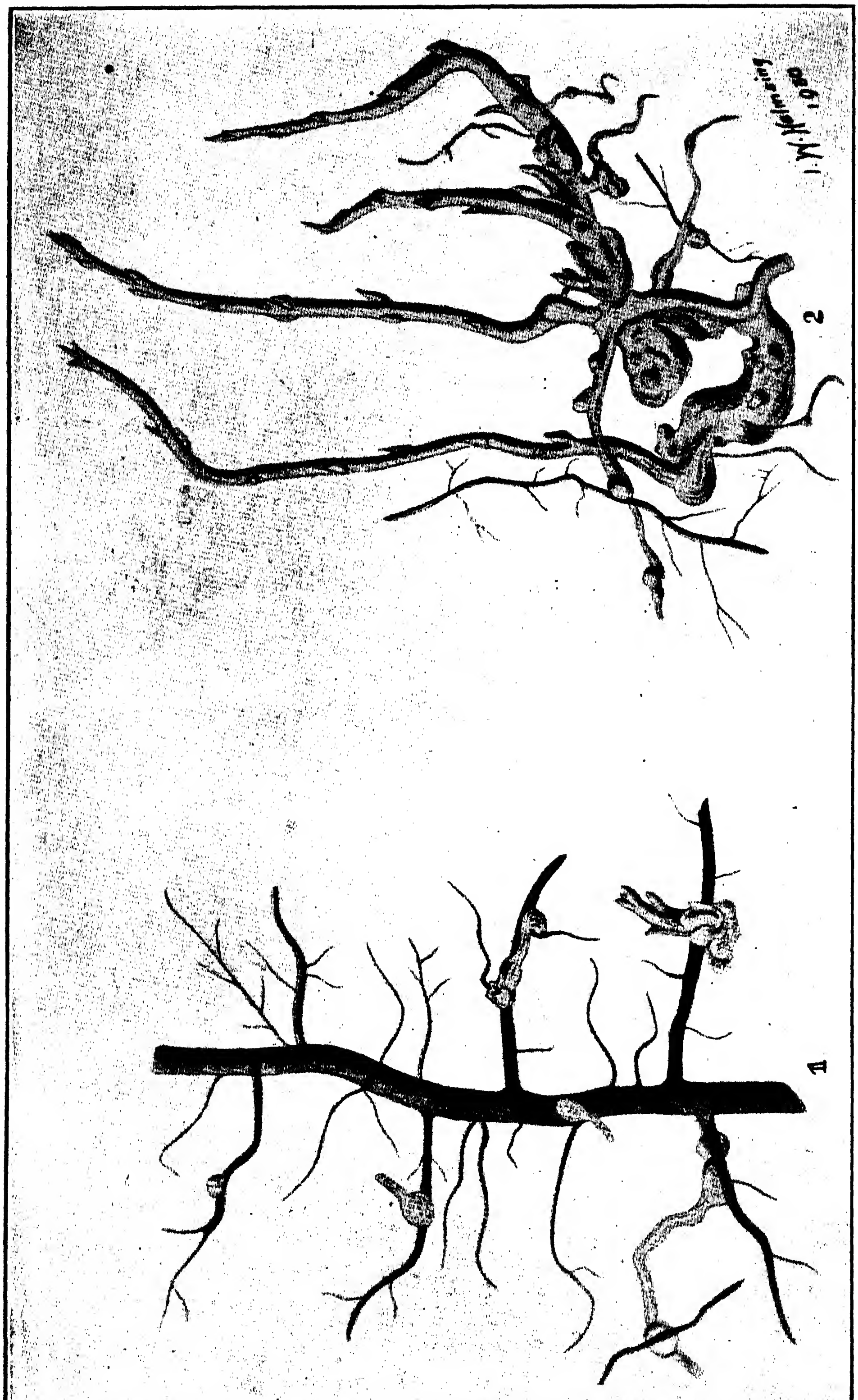


PLATE 119.
(For description of plate, see page 225.)

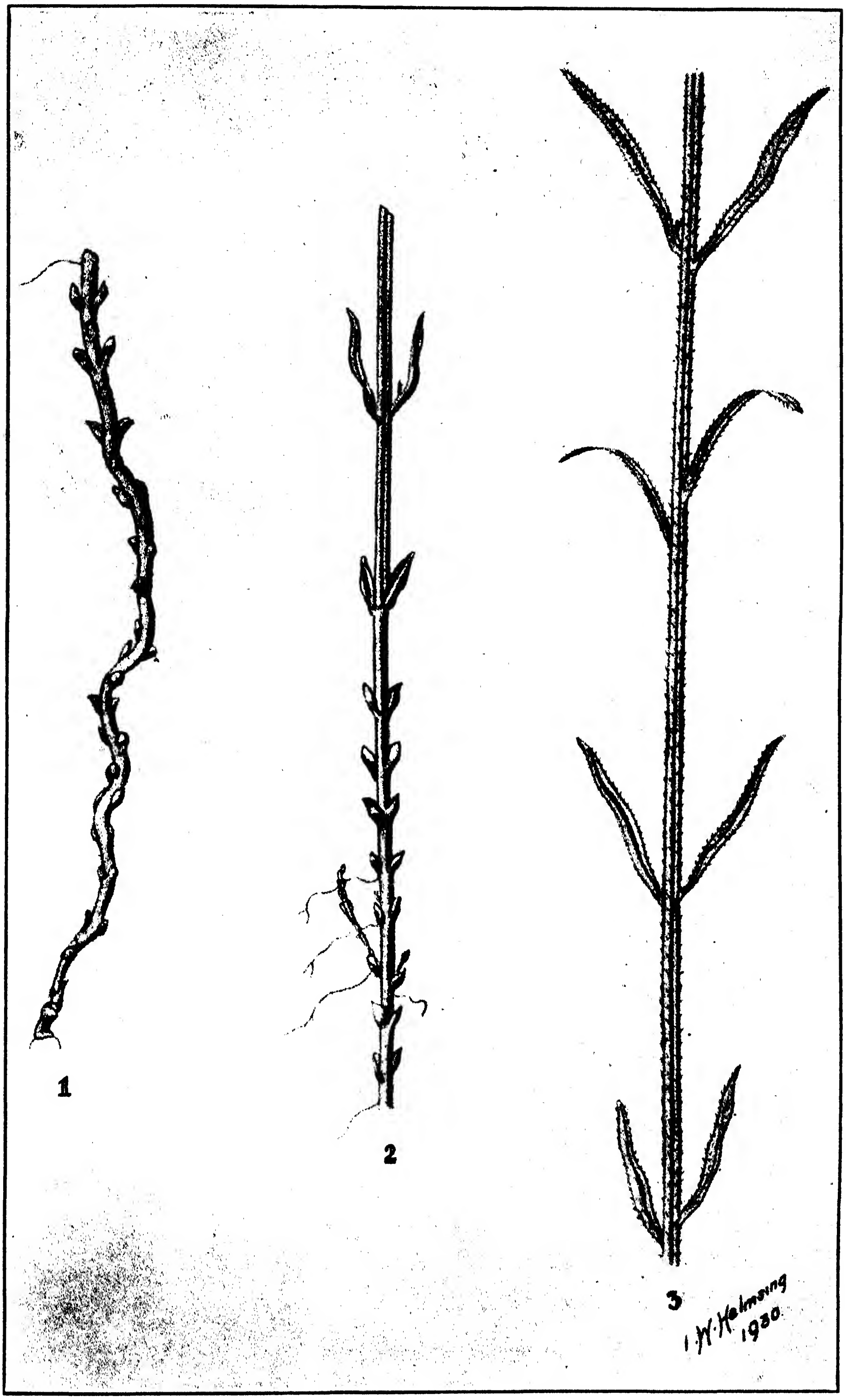


PLATE 120.
(For description of plate, see page 225.)

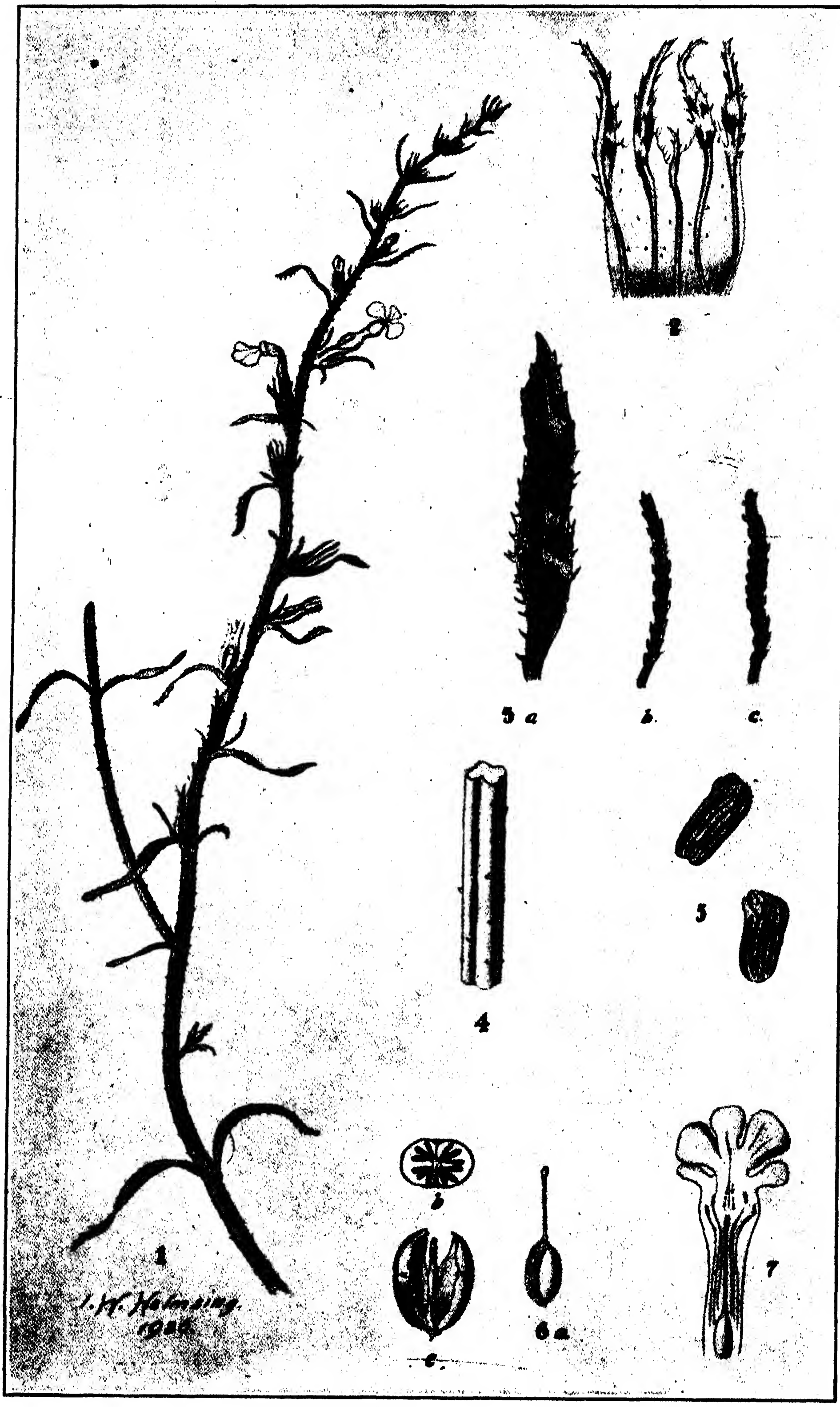


PLATE 121.
(For description of plate, see page 225.)

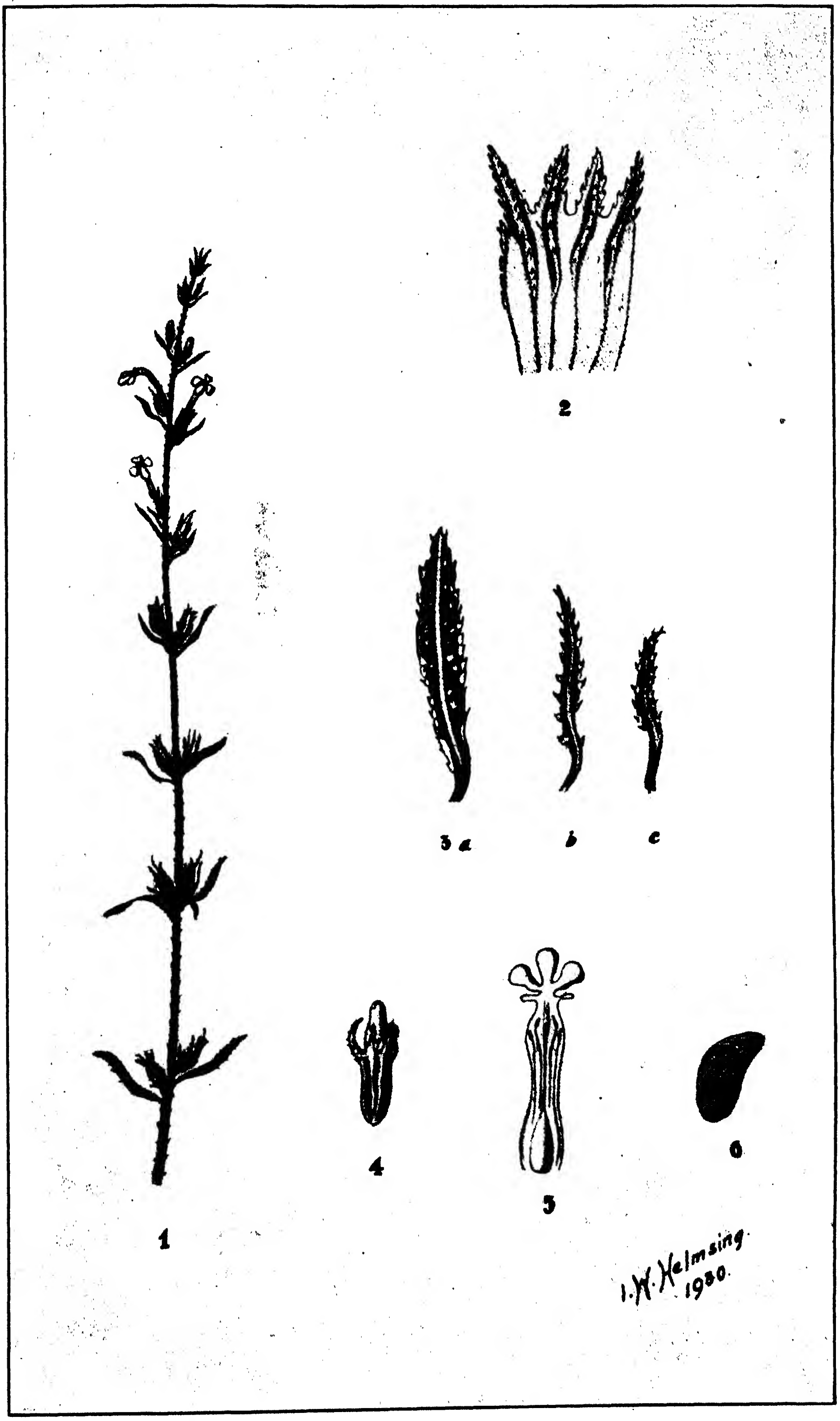


PLATE 122.
(For description of plate, see page 225.)

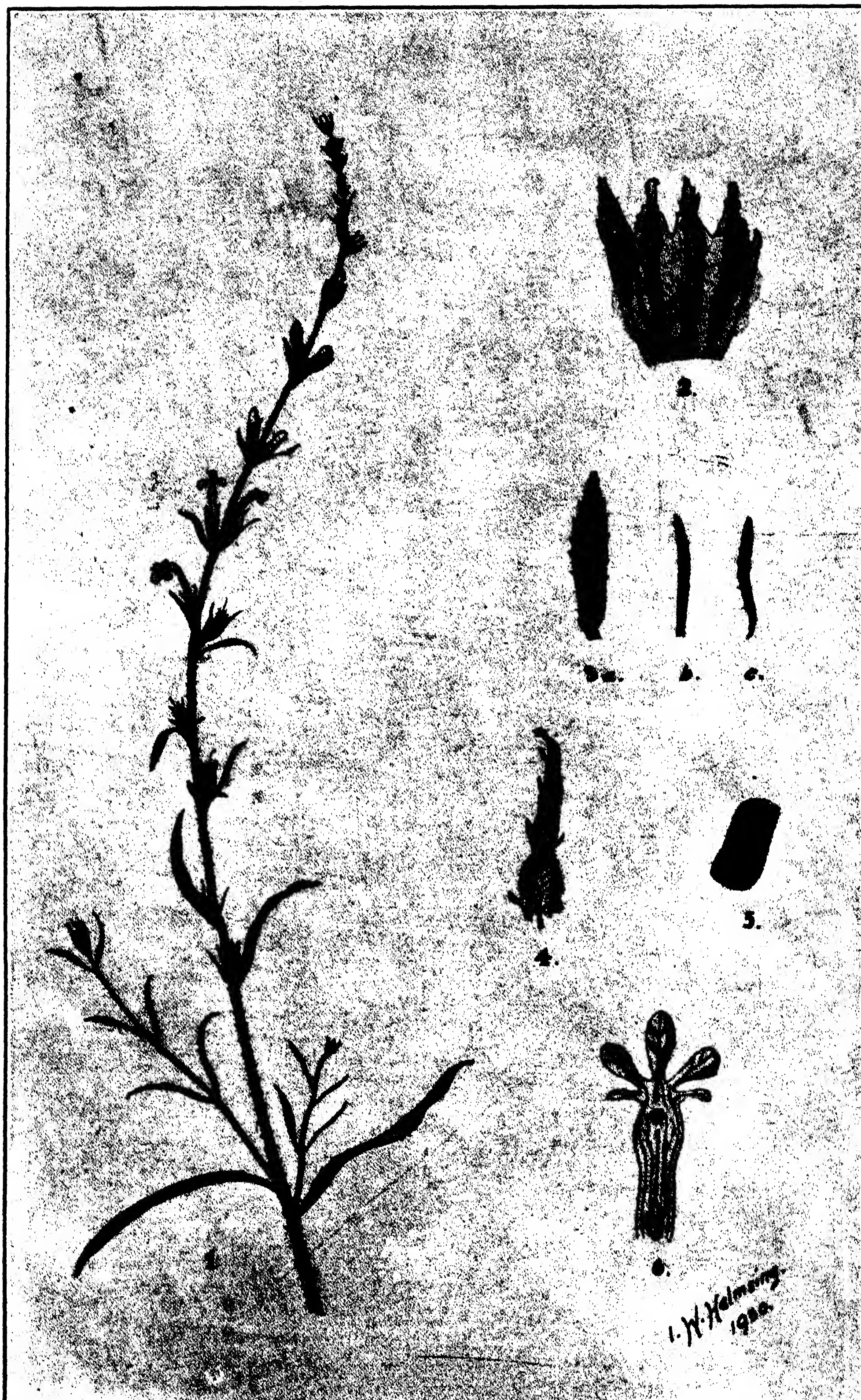


PLATE 123.
(For description of plate, see page 225.)

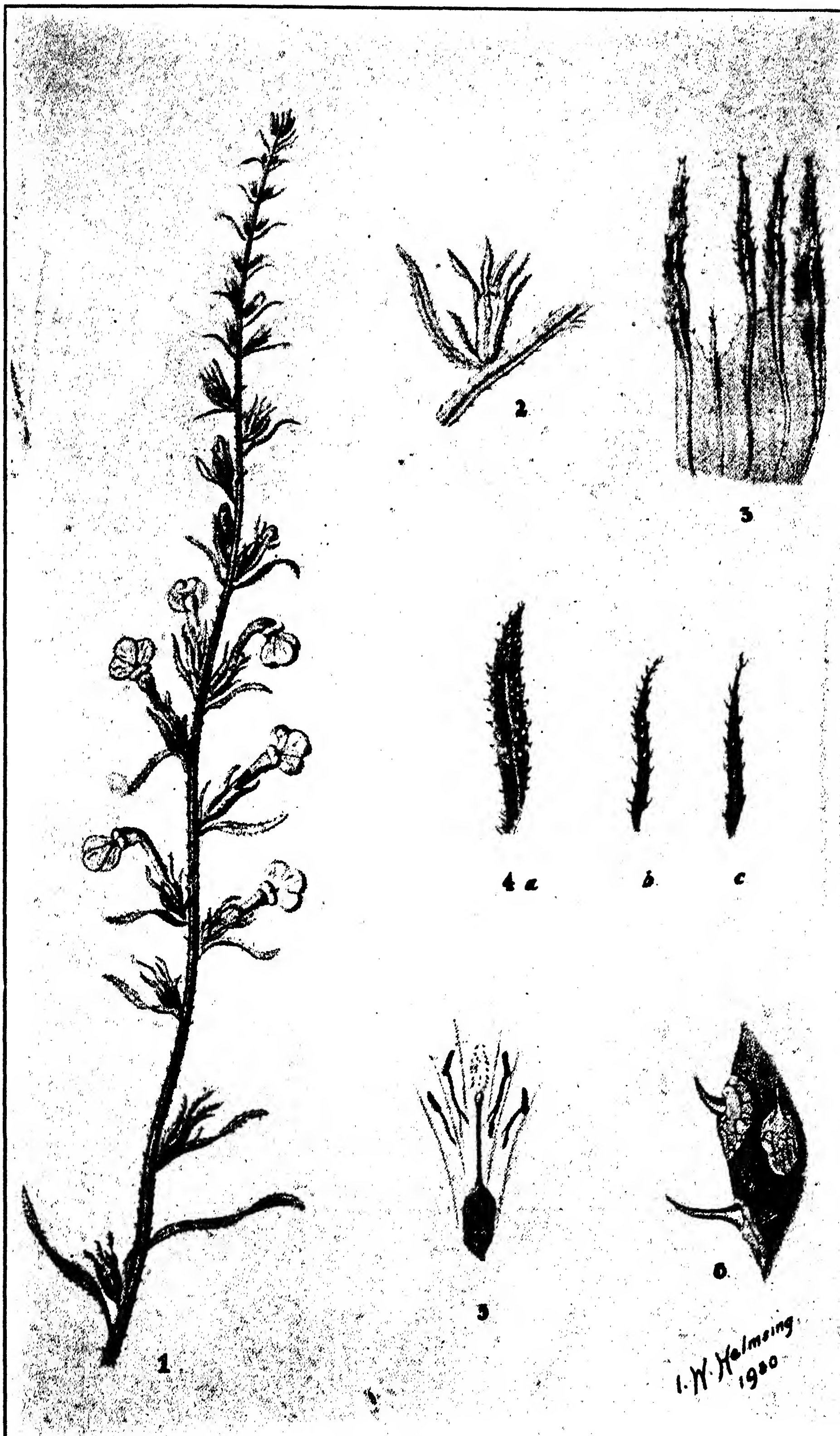


PLATE 124.
(For description of plate, see page 225.)

PLATE VII.

(For description of plate, see page 225.)

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD DECEMBER 16, 1931, TO MARCH 15, 1932

Date	Per Pound	Per Ton	Remarks
Dec. 16, 1931	3.105¢	$62.10	Cubas, 3.10, 3.11.
" 18	3.10	62.00	Cubas.
" 21	3.09	61.80	Porto Ricos.
" 22	3.095	61.90	Philippines, 3.09, 3.10.
" 23	3.10	62.00	Porto Ricos.
" 28	3.12	62.40	Porto Ricos.
" 29	3.14	62.80	Porto Ricos, 3.13; Cubas, 3.15.
" 30	3.18	63.60	Cubas.
" 31	3.20	64.00	Cubas.
Jan. 4, 1932	3.15	63.00	Porto Ricos.
" 7	3.135	62.70	Philippines, 3.10; Cubas, 3.17.
" 8	3.1733	63.47	Philippines, Porto Ricos, 3.15; Cubas, 3.17, 3.20.
" 9	3.20	64.00	Cubas.
" 12	3.165	63.30	Cubas, Porto Ricos, 3.17; Porto Ricos, 3.16.
" 13	3.16	63.20	Porto Ricos.
" 14	3.155	63.10	Cubas, 3.16; Porto Ricos, 3.15.
" 15	3.145	62.90	Cubas, 3.15; Cubas, Porto Ricos, 3.14.
" 18	3.13	62.60	Porto Ricos.
" 19	3.11	62.20	Cubas, 3.12; Philippines, 3.10.
" 20	3.10	62.00	Porto Ricos, Philippines.
" 21	3.08	61.60	Cubas, Porto Ricos.
" 30	3.06	61.20	Cubas.
Feb. 1	3.045	60.90	Cubas, 3.05, 3.04.
" 2	3.02	60.40	Porto Ricos.
" 3	3.00	60.00	Porto Ricos.
" 5	2.965	59.30	Porto Ricos, 2.98, 2.97; Cubas, 2.96; Cubas, Philippines, 2.95.
" 6	2.94	58.80	Philippines.
" 9	2.92	58.40	Porto Ricos, 2.94; Cubas, 2.92, 2.90.
" 10	2.90	58.00	Philippines, Porto Ricos, 2.90.
" 11	2.94	58.80	Porto Ricos.
" 15	2.995	59.90	Porto Ricos, 3.00; Cubas, 2.99.
" 16	2.96	59.20	Cubas, 2.97; Philippines, 2.95.
" 18	2.975	59.50	Porto Ricos, 2.98; Porto Ricos, Philippines, 2.97.
" 19	2.955	59.10	Cubas, 2.97; Porto Ricos, 2.94.
" 20	2.92	58.40	Porto Ricos.
" 23	2.895	57.90	Cubas, Porto Ricos, 2.90; Cubas, 2.89.
" 24	2.88	57.60	Philippines.
" 27	2.865	57.30	Porto Ricos, 2.88, 2.85.
" 29	2.85	57.00	Philippines.
Mar. 2	2.86	57.20	Porto Ricos, 2.85; Philippines, 2.87.
" 3	2.855	57.10	Porto Ricos, Cubas, 2.86; Philippines, 2.85.
" 4	2.845	56.90	Porto Ricos, Philippines, 2.85; Porto Ricos, 2.84.
" 5	2.81	56.20	Porto Ricos.
" 9	2.795	55.90	Porto Ricos, Philippines, 2.81; Philippines, 2.80; Cubas, 2.79, 2.78.
" 10	2.77	55.40	Cubas, 2.79; Philippines, 2.75.
" 11	2.765	55.30	Cubas, 2.76, 2.77.
" 12	2.76	55.20	Cubas.
" 14	2.775	55.50	Philippines, 2.77; Porto Ricos, 2.78.
" 15	2.76	55.20	Philippines.

3-7-3

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXVI THIRD QUARTER, 1932 No. 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Weather and Crop Relationships at the Honokaa Sugar Company:

Our previous weather studies were based on typical irrigated and unirrigated plantations. Herein we present the case of Honokaa Sugar Company, which belongs to neither of the two groups mentioned above and which has many peculiar complex problems of its own. But here also we find that the general weather influences are of the same nature as found elsewhere and that we are in a position to measure the magnitude of these influences. This study further confirms our belief that no matter where we are situated or what our particular problems are, we have to reckon with weather as one of the major factors in crop production.

Response of Cane Plants to Soil Sterilization:

The effect of soil sterilization by steam, formaldehyde and chloropicrin is reported. A great increase in top and root growth of cane is shown in the sterilized over the unsterilized pots. The results of the examination of roots and soil for Pythium or nematode infestation are reported. A summary of the work of other investigators on the subject of soil sterilization is given, in which explanations are presented for the differences observed in plant growth in sterilized and unsterilized soils.

Pedigrees of Some of the New Seedlings:

The pedigrees for some of the more interesting combinations made during the 1931-1932 crossing season are listed. The crosses which are considered suited to special agricultural conditions, as mauka unirrigated, makai irrigated, etc., are grouped under these headings. The crosses with the newly imported *robustum,* Indian, and Australian blood lines show the use of a wide range of the commercial Hawaiian varieties.

Plant Wilt and Its Relation to the Rate of Water Supply and Water Demand:

This paper is a non-technical discussion of the factors which bring about the condition of wilt in plants. It is argued that such conditions are brought about by

a demand for water by the leaves at a rate greater than the potential rate of supply by the roots. A careful distinction is made between "temporary wilt" and "permanent wilt."

A Summary of Recent Irrigation Studies and Some Suggestions for Future Investigations:

The general conclusions from three years' intensive study of plant and water relations in Hawaii are briefly summarized. In general, local findings are in accord with the results of extensive studies elsewhere.

Future work may well be founded upon these conceptions. Studies of the role of soil moisture in cane ripening and of the attributes of drought resistant varieties are suggested as worthy fields of investigation.

Hilo Forest Reserve:

A very clear and illuminating account of the work accomplished in the Hilo Forest Reserve during the past ten years by Forestry Unit No. 3 in cooperation with the Territorial Division of Forestry is given.

The Recovery of Potash from Molasses:

An account is given of how one plantation is burning molasses to recover the potash. The molasses ash is placed in the irrigation water by means of a device designed for the purpose.

Plantation Interval Tests:

A presentation and discussion of results from typical irrigation interval tests on the plantations of the Pioneer Mill Company, Koloa Sugar Company, and Lihue Plantation Company are contained in this issue.

The trends indicated by these experiments may prove valuable aids in our interpretation of the response of cane growth to soil moisture, and in the practical manipulation of our field irrigations.

A Summary of Recent Irrigation Studies and Some Suggestions as to Future Investigations

By H. A. Wadsworth

In general, irrigation investigations at the Experiment Station of the H. S. P. A. have, for the past three years, been directed towards verifying, under local conditions, certain basic conceptions of soil moisture and plant and water relations, which have been expounded elsewhere.

With certain minor exceptions, primarily of academic interest, these basic conceptions have been found applicable to local conditions. Future work in irrigation studies may be based upon a foundation which is theoretically sound in view of the exhaustive studies made eslewhere and the demonstrated concordance of local results.

These conceptions may be summarized as follows:

(1) All soils exhibit a critical soil moisture content which cannot be exceeded when free drainage is provided. Naturally, this soil-moisture percentage varies with the kind of soil, being low for gravelly soils and high for finely divided colloidal soils. This critical constant may be determined by simple laboratory means. This procedure permits the location of areas requiring expensive and uneconomic "dry spotting."

(2) All plants growing in a given soil give evidence of soil-moisture shortage at approximately the same soil-moisture content. With sugar cane this evidence of soil-moisture shortage occurs in the form of growth cessation and not as evidently flaccid leaf tissue. This principle permits the determination of the lower limit of available soil-moisture by means of rapidly growing plants in small containers.

(3) Growth of sugar cane is equally rapid between the critical soil-moisture contents mentioned above. Consequently, it is neither possible nor desirable to maintain a predetermined moisture content such as the so-called "optimum moisture content." Several field observations have demonstrated the soundness of this conception, which the detailed tank work has demonstrated and which theory demands. At Ewa growth measurements in the field have indicated a period before the cessation of growth in complete concordance with the desirable intervals as determined by Alexander. At Waimanalo similar methods have demonstrated adequate soil-moisture penetration at critical points along the long lines in the experiment recently reported.

Naturally, this conception gives a new point of view which is of value in interpreting the results of the classical "interval tests." It is evident that:

(1) Irrigation at more frequent intervals than that indicated by the criterion of growth cessation adds nothing to the rate of growth and is wasteful of water.

(2) Irrigation at intervals longer than that indicated by the criterion of growth cessation is wasteful of growing time. Moreover, a permanent handicap may be encountered if the plants are allowed to suffer at critical periods of growth. This aspect deserves further study.

Suggested Investigations

In view of the uniformity of local results with those secured elsewhere, future work in irrigation research may well center about the relation of soil-moisture to sugar formation.

Tradition holds that irrigation should be withheld for 60 to 90 days prior to the proposed date of harvest for maximum sugar yields. Recent evidence on this point is contradictory and inconclusive. The relation between available plant nutrients, particularly nitrogen, during ripening, available soil-moisture and total sugar is not well understood. On some plantations irrigation is "tapered off," that is, the long period of drying off is broken into shorter periods of increasing length. The reason for this arbitrary practice is not clear.

The comprehensive attack of this problem requires growing of cane plants under such conditions that unquestioned soil-moisture control is possible. The tanks at Waipio provide such control and are available. Although well adapted to qualitative work, such as studies of changes in rates of growth, they are strictly limited in their use in studies of sugar formation.

It seems well established that sucrose once synthesized and stored in a cane is subject to reversion to simple hexoses through the action of the enzyme invertase. If the recoverable sugar in a cane at harvest is a function of the relative activity of invertase, other things being equal, it seems logical to suppose that cane grown in tanks might give entirely different figures for quality ratios than cane of similar age in the environment of a completely closed-in field, although adjacent tanks should be mutually comparable.

We have some evidence that the temperature inside a closed-in cane field is significantly lower than the temperature in the shade at the tanks. Little is known of the effect of temperature upon the activity of invertase. The fact remains, however, that in a crop grown for two summers and one winter the quality ratio secured from the tanks was significantly poorer than in the field control. In the next crop, covering one summer and two winters, the quality ratios from the tanks were better than the field control.

The leads seem worthy of further study as contributing to the general knowledge of cane ripening.

Without detail as to procedure it is suggested that the problem of the effect of soil-moisture, available plant nutrients and temperature upon cane ripening be actively studied in the tank farm and as much adjacent area as is available. One great advantage lies in the fact that little or no new equipment would be required. All costly apparatus is on hand. If intelligently planned and actively prosecuted, such a project would contribute materially to our knowledge of cane ripening.

Considerable work has been done in an effort to determine the significance of so-called drought resistance in some cane varieties. Results from one crop indi-

cate that recognized drought resistant varieties possess deep, well-ramified root systems, which provide extensive soil-moisture reservoirs and leaf systems of such character that water expenditure by transpiration is at a slow rate. Study of this problem throughout the ratoon crop is essential, however, for unquestioned conclusions.

This work is fundamental in character. The principal costs involved are in labor, mainly "off-season" labor.

It is felt that these two major research problems will form a sufficiently heavy load for the personnel of the irrigation staff as now organized. Other enterprises, such as a study of the surface forces in local soils and the physical properties of local soils are too academic to demand attention during the current emergency. They form attractive fields of research, however, and may well be resumed at a later date.

It should be remembered that the prosecution of investigational projects forms only one part of the work of the available personnel. Plantation advice with respect to methods of irrigation and water measuring is time consuming and of compelling importance.

Manufacture and Distribution of Potash From Molasses

By H. S. Harkness
Chemist, Hawaiian Sugar Company

The burning of molasses for potash recovery is not new. During 1915, several Hawaiian plantations burned their molasses for the potash and at that time it was a very profitable undertaking as potash was then worth about 20 cents per pound. The present cost of potash is around 4 cents per pound, but since there is practically no sale for molasses the Hawaiian Sugar Company determined to see if they could not profitably burn their final molasses and recover the potash in the ash.

Production

Three molasses burning furnaces were erected in January, 1932. The first furnaces proved unsatisfactory, chiefly because of the method of dehydrating the molasses. The furnaces were then rebuilt and revolving drums with water-cooled shafts were installed in each unit. The function of the drum is to preheat the molasses and remove as much water as possible before the molasses reaches the fire.

We are now able to burn from 18 to 20 tons of molasses and produce from 3,000 to 3,400 pounds of ash daily. Eight men are required to operate the furnace: two for cooling and bagging the ash and three men per shift to tend the furnaces, one man being in charge of each unit. Fig. 1 shows in some detail

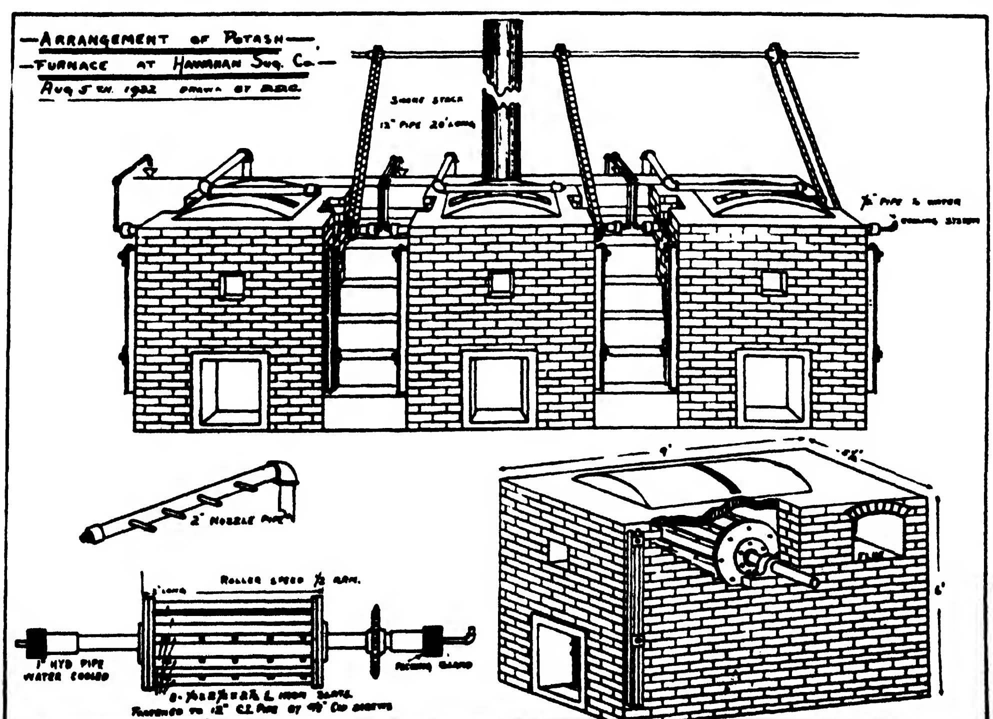


Fig. 1. Showing arrangement of molasses burning furnaces.

Fig. 2. Showing molasses ash drums in operation.

the general arrangement of the furnaces. Those desiring a full description of them and their operation are referred to a report, "Potash Recovery From Molasses," by the writer, and published in *Reports of the Association of Hawaiian Sugar Technologists for 1932.*

Recovery

For every ton of molasses burned there is produced about 170 pounds of ash. The ash is from 33 to 37 per cent K_2O or about 56.1 pounds of potash for each ton of molasses burned or a recovery of about 2.5 to 3.0 per cent potash on molasses.

Field Application

After producing the ash we then had the problem of proper field distribution. Spreading by hand would be too expensive as it would mean an extra round by the fertilizer gang. Also the ash is very light and dusty and it would probably be a very disagreeable job.

Various methods of distributing the ash in the irrigation water were tried. Drums or barrels, such as we use for the distribution of nitrate of soda, were tried, with no success. The insoluble part of the ash would settle and pack in a

Fig. 3. Showing false bottom in one of the drums.

very firm layer on the bottom of the drum and would not flow. False bottoms were then made and installed in the drums at an abrupt angle so that all movement was toward the outlet cock. We also installed 1½-inch outlet cocks to obviate clogging. Screens of about the same mesh as window screen were used on top of the drums to remove pieces of clinker or carbon so that no large pieces could go through to block the outlet. This arrangement works very well and requires one man for its operation. The drums are used in sets of three: two large drums are used as stock tanks and are emptied alternately and the small drum is used as a regulating tank so that the same amount of ash is constantly flowing in the water. The drums can be used over any ditch in the field and are best suited for the supply of 4 to 6 irrigators, as their capacity is limited. Fig. 2 shows the drum arrangement in operation, and Fig. 3 a view of the false bottom in one of the drums.

Perhaps the best apparatus developed for the distribution of the ash in irrigation water consists of a hopper with a variable opening in the bottom through which a corrugated plunger, made of heavy wire, operates from an eccentric shaft which is driven by a waterwheel attached to the hopper. The machine is constructed almost entirely of wood and is light enough so that two or three men can easily carry it from place to place. In operation, the machine is set over any

Fig. 4. Showing ash distributing machine.

main or level ditch supplying the acreage over which it is desired to distribute the ash, and the waterwheel lowered into the water.

After the machine is in place and the hopper filled with ash its operation is practically automatic. The corrugated plunger keeps a stream of ash constantly flowing into the water and as long as the ash is dry there is little to do except to keep the hopper full and remove occasional clinkers or lumps which obstruct the flow. Damp ash has a tendency to stick and requires frequent poking with a stick. The machine is very elastic with respect to capacity and can be used to supply either small or large gangs. We have found little difficulty in feeding up to 1000 pounds per hour with one man and he has time to weigh the ash.

Production Costs

It is rather a difficult matter to work out a fair cost figure on ash production for this first period of operating (to July 1, 1932) as there must be included not only ordinary operating and upkeep costs but also the rebuilding costs, making, however, no charge for the molasses burned. We therefore propose to present two sets of cost figures:

Case 1. Showing actual figures to July 1, 1932, which include all rebuilding, upkeep and operating expenses.

Case 2. Showing calculated costs over a six-month period, when burning

an average of 20 tons of molasses per day, and including only ordinary upkeep and operating expenses.

Going back to Case 1, we have the following figures:

Labor	$1,855.75
Supplies	529.18
Total expense	$2,384.93

Molasses burned	1,266 tons
Ash produced	215,220 pounds
Potash in ash at 33 per cent	71,022 pounds

Value of potash at 4.106 cents per pound	$2,916.16
Cost of potash (labor and supplies)	2,384.93
Saving	$ 531.23

This amounts to 0.748 cents per pound of potash and gives a value to the molasses of 42 cents per ton. Using 120 pounds of potash per acre it means a saving of 89.76 cents per acre or $897.60 per 1000 acres.

Case 2:

Labor (156 days at $8.94)	$1,394.64
Upkeep	200.00
Total expense	$1,594.64

Molasses burned at 20 tons per day	3,120 tons
Ash produced at 170 pounds per ton molasses	530,400 pounds
Potash in ash at 33 per cent	175,032 pounds

Value of potash at 4.106 cents per pound	$7,186.81
Cost of potash (labor, etc.)	1,594.64
Saving	$5,592.17

Per pound of potash this amounts to 3.1949 cents and gives to the molasses a value of $1.79 per ton. Using 120 pounds of potash per acre it means a saving of $3.83 or $3830.00 per 1000 acres.

From the above figures it is self-evident that whenever we are able to sell our molasses for more than $1.79 per ton it will not pay to burn it for the potash.

Field Application Costs

We are not at the present time able to give positive figures on the cost of applying molasses ash as fertilizer and the figures which will be given should be regarded as simply an indication of what to expect.

Ordinarily we use a mixed fertilizer containing definite proportions of nitrogen, phosphoric acid and potash, which is known as the HS2 formula. It must neces-

Fig. 5. Ash distributing machine in operation.

sarily be spread by hand as we are unable to use a fertilizer gun or similar apparatus on account of its physical condition. However, when applying molasses ash we use a mixture called HS3, which contains about double the percentage of nitrogen and phosphoric acid as HS2, but no potash. Where we used 5 bags per acre of HS2 we now use only 2.75 bags of the more concentrated HS3.

The *ukupau* for HS2 was 10 bags per man and when the HS3 mixture was started we still held the men to the old *ukupau*. This was made possible by the fact that the HS3 mixture is not lumpy and is fairly free running and we are able to use a fertilizer gun (patterned after the McBryde fertilizer gun) in its application. Where one man formerly covered 2 acres per day he now covers 3.6 acres.

We have just finished fertilizing a 101.78-acre field using the HS3 mixture and molasses ash. The HS3 was applied, using the fertilizer gun and the molasses ash by means of the water wheel distributing machine. The HS3 distribution required 28 man days to complete and the ash distribution 12 man days, making 40 man days for the complete application. If the HS2 had been used it would have taken a total of 50 man days, so there is a gain of approximately 10 man days. Trucking and mule expense are about the same in both cases, due chiefly to the concentrated bulk of HS3 and the light weight of the molasses ash.

Taking everything into consideration we find that we are able to apply HS3 and molasses ash a shade cheaper than the HS2 mixture. However, if we had to apply HS3 by hand the remainder would be much in favor of the HS2 fertilizer.

Under the present condition of the world molasses market there seems to be but little probability of selling more than a small percentage of our molasses output. There is always a little of the molasses used for stock food; on plantations favorably situated considerable of their molasses is being applied to their fields at relatively small cost. Many plantations, however, find field application a costly operation. To such plantations this method of molasses burning will not only solve the problem of molasses disposal but will also provide for a considerable amount of the potash requirements of the soil.

Pedigrees of Some of the 1932 Seedlings

By C. G. Lennox and A. J. Mangelsdorf

The 1931-1932 crossing season provided an abundance of new and promising breeding material with which to work. Weather conditions during the tasseling and germinating season were good.

Well over a million seedlings were germinated, from which some 270,000 were selected for potting and subsequent testing in the field.

Some of the more interesting combinations, together with their pedigrees are set forth in the following pages.

Crosses with P. O. J. 2878

P. O. J. 2878 gives promise of being an excellent breeding cane. Its seedlings are, on the whole, remarkably clean, attractive and vigorous.

P. O. J. 2878 was used extensively in crosses this season, both as a male and as a female parent.

Crosses Between P. O. J. 2878 and Thick Canes for Makai Conditions

Cross No. 2523 (and others)
21,000 seedlings
- H 109
  - Lahaina
  - x
  - ?
- x
- P. O. J. 2878
  - P. O. J. 2364
    - P. O. J. 100
      - Bandjermasin hitam
      - x
      - Loethers
    - x
    - Kassoer
      - Cheribon
      - x
      - Spontaneum
  - x
  - E. K. 28
    - Parentage uncertain

Cross No. 1736....................
720 seedlings
- 26 C 113
  - Yellow Caledonia
  - x
  - H 109
- x
- P. O. J. 2878

Cross Nos. 705 and 771............
990 seedlings
- 25 C 28
  - Yellow Caledonia
  - x
  - H 109
- x
- P. O. J. 2878

Cross No. 146 and others..........
3,370 seedlings
- Lahaina
- x
- P. O. J. 2878

Cross 1559 ....
1,210 seedlings
- P. O. J. 2878
- x
- 27-8101
  - 25 C 14
    - Yellow Caledonia
    - x
    - H 109
  - x
  - Badila

Crosses Between P. O. J. 2878 and Hardy Canes for Mauka and Middle Belt Conditions

Cross Nos. 116 and 240, 1,000 seedlings	26 Q 2873 x P. O. J. 2878	U. D. 88 x H 109	
Cross No. 1567, 630 seedlings	Natal Uba x P. O. J. 2878		
Cross No. 136 (and others), 6,950 seedlings	P. O. J. 213 x P. O. J. 2878	Cheribon x Chunnee	
Cross No. 243, 572 seedlings	U. D. 50 x P. O. J. 2878	Uba x D 1135	
Cross No. 142, 604 seedlings	28-4615 x P. O. J. 2878	Uba x H 456	
Cross No. 187, 530 seedlings	28-1739 x P. O. J. 2878	P. O. J. 213 x H 109	
Cross No. 246, 630 seedlings	25 U. H. 13 x P. O. J. 2878	Uba x H 109	
Cross No. 343, 420 seedlings	Co. 281 x P. O. J. 2878	P. O. J. 213 x Co. 206	Ashy Mauritius x S. spontaneum

Crosses Between Large-stalk Canes for Makai Conditions

Cross No. 494, 590 seedlings	H 109 x 28-2366	Yellow Caledonia x Badila
Cross No. 849, 280 seedlings	25 C 28 x Cavengerie	Yellow Caledonia x H 109
Cross No. 1509, 660 seedlings	27 C 445 x 20 S 16	Yellow Caledonia x H 109; Striped Mexican x ?
Cross No. 750, 490 seedlings	26 C 189 x H 456	Yellow Caledonia x H 109; H 240 x ?
Cross No. 453, 570 seedlings	28-227 x H 456	P. O. J. 2725 x 25 C 4; H 240 x ?

Cross No. 210	342 seedlings	28-859	P. O. J. 2364 x 26 C 270
		x	
		H 456	H 240 x ?
Cross No. 88	380 seedlings	Lahaina	
		x	
		29-621	P. O. J. 2364 x D 117

Crosses Between Hardy Canes for Mauka and Middle-belt Conditions

Cross No. 354	630 seedlings	U. D. 50	Uba x D 1135
		x	
		30-3391	Kassoer x H 109
Cross No. 369	360 seedlings	26 Q 2873	U. D. 88 x H 109
		x	
		K 202	D 1135 x Tip
Cross No. 1619	825 seedlings	P. O. J. 213	Cheribon x Chunnee
		x	
		28-4830	Natal Uba x H 456
Cross No. 223	400 seedlings	Striped Tip	
		x	
		28-4493	Uba x H 456
Cross No. 1628	255 seedlings	Kassoer	Cheribon x S. spontaneum
		x	
		Manoa 213	Badila x ?
Cross No. 1532	530 seedlings	P. O. J. 2364	P. O. J. 100 x Kassoer
		x	
		28-4488	Uba x H 456
Cross No. 173	620 seedlings	28-2073	P. O. J. 2364 x 26 C 270
		x	
		28-4456	Uba x H 456

Crosses Made at Mapulehu, Molokai, Utilizing the Newly Imported Breeding Canes

Robustum Group

The *robustum* group, imported from New Britain and New Guinea through the efforts of C. E. Pemberton, are clean, hard, sparse-tasseling canes. They tasseled for the first time this season, and were used in many crosses, some of which are shown below.

Cross No. 3326.................... 250 seedlings
- 26 C 48 (Yellow Caledonia x H 109)
- x
- Mol. 1227 (New Guinea robustum)

Cross No. 3234.................... 300 seedlings
- 27-8101 (25 C 14 x Badila)
- x
- Mol. 1395 (New Guinea robustum)

Cross No. 3260.................... 300 seedlings
- S. C. 12/4 (B 6835 x ?)
- x
- Mol. 1194 (New Guinea robustum)

Cross No. 3325.................... 300 seedlings
- Striped Tip
- x
- Mol. 1227 (New Guinea robustum)

Cross No. 3227.................... 300 seedlings
- H 109
- x
- Mol. 1238 (New Guinea robustum)

Cross No. 3336.................... 300 seedlings
- M 313 (Striped Tip x ?)
- x
- Mol. 1296 (New Guinea robustum)

Indian Group

These are slender, vigorous canes from crosses made in India by U. K. Das. They were crossed extensively with local canes with the aim of combining their hardiness with a satisfactory diameter and sucrose content. The following are some typical combinations:

Cross No. 3213.................... 300 seedlings
- 26 C 113 (Yellow Caledonia x H 109)
- x
- Mol. 466 (Purple Mauritius x Katha)

Cross No. 3165.................... 300 seedlings
- H 109
- x
- Mol. 680 (Saretha x S. spontaneum)

Cross No. 3057.................... 300 seedlings
- Striped Tip
- x
- Mol. 556 (D 74 x S. spontaneum)

Cross No. 3216 300 seedlings	H 109 x Mol. 1020	 Barbados 6308 x S. spontaneum
Cross No. 3236 100 seedlings	P. O. J. 2727 x Mol. 352	P. O. J. 2364 x S. W. 3 Putlikhajee x S. spontaneum
Cross No. 3525 300 seedlings	P. O. J. 2878 x Mol. 760	 Saretha x S. spontaneum
Cross No. 3217 300 seedlings	27 C 376 x Mol. 123	Yellow Caledonia x H 109 Putlikhajee x S. spontaneum
Cross No. 3231 300 seedlings	27-8101 x Mol. 928	25 C 14 x Badila B 6308 x S. spontaneum

Crosses Made at Mapulehu, Molokai, Utilizing the Newly Imported Breeding Canes

Australian Group

These are for the most part large-stalk canes from parentages reputed to have good sucrose qualities, together with resistance to certain diseases. This group resulted from crosses made in Australia by C. G. Lennox. They may be expected to give large-stalk seedlings suitable for irrigated conditions.

Cross No. 3168 .... 300 seedlings	H 109 x Mol. 3934	P. O. J. 2878 x 27 M Q 629	Oramboo x M 1900
Cross No. 3198 .... 250 seedlings	26 C 189 x Mol. 3656	Oramboo x 28 M Q 298	Oramboo x Q 813
Cross No. 3239 .... 300 seedlings	Mol. 3726 x H 456	H Q 409 x China	
Cross No. 3235 .... 300 seedlings	Mol. 1715 x 26 C 188	H Q 409 x 21 N G 22	
		Yellow Caledonia x H 109	
Cross No. 3138 .... 150 seedlings	H 109 x Mol. 1709	H Q 409 x 21 N G 22	
Cross No. 3510 .... 100 seedlings	Mol. 3738 x 26 C 270	P. O. J. 2878 x 28 M Q 674	Badila x Q 813
		Yellow Caledonia x H 109	
Cross No. 3167 .... 150 Seedlings	H 109 x Mol. 3783	P. O. J. 2878 x 28 M Q 674	Badila x Q 813

Q = Queensland.
H Q = Hambledon Queensland.
M Q = Macknade Queensland.
M = Mauritius.
N G = New Guinea.
Mol. = Molokai.

Weather and Crop Relationships at the Honokaa Sugar Company

By U. K. Das

A study of the weather and crop relationships at the Honokaa Sugar Company is of more than passing interest, for the conditions encountered at Honokaa are quite different from those obtained in the other two types of plantations which we have studied heretofore. These two types represent extreme conditions: Pepeekeo an entirely unirrigated plantation where rainfall is generally abundant, though not always well distributed, and Ewa where the deficiency of rainfall is more than made up by a plentiful supply of irrigation water. At Honokaa, the rainfall is neither sufficient to promote continuous growth, nor is it always dependable. It is, nevertheless, the only source of moisture in about half the total area of the plantation. The other half receives occasional irrigation if and when there is enough water available after the fluming operations.

The question naturally arises: Are the weather influences as great at Honokaa as at Pepeekeo and Ewa? If so, can we measure them?

Past History of Honokaa Yields

It may be said without exaggeration that the past crops of the Honokaa Sugar Company have been more exposed to shifting influences than any other place we know of. The constant change of varieties that started way back in 1907 have continued almost to date, with the result that it has been found impossible to segregate a sufficient number of fields growing the same variety of cane over a series of years.

The cultural practices also have varied so much in the past thirty years that in studying the crop yields there always remains a reasonable doubt in one's mind as to whether the trend of increase or decrease in yield between two groups of years is due to changes in the cultural or fertilizer policy or something else.

Coupled with these major disadvantages in disentangling the crop statistics, there is the further handicap imposed by the absence of data as to the amount of irrigation water applied to the fields from season to season.

While, therefore, the absence of sufficient statistics render an exhaustive study of questionable value, there is really no need for such a detailed study of the Honokaa crop data. It will be enough for our purpose if we can show that the weather influences at Honokaa are in general agreement with similar influences at Pepeekeo and at Ewa.

Honokaa Cane Yields

Table I and Fig. 1 show the cane yield per acre from 1909 to 1931. The yields of the Kukuihaele Section (previously the Pacific Sugar Mill) and the

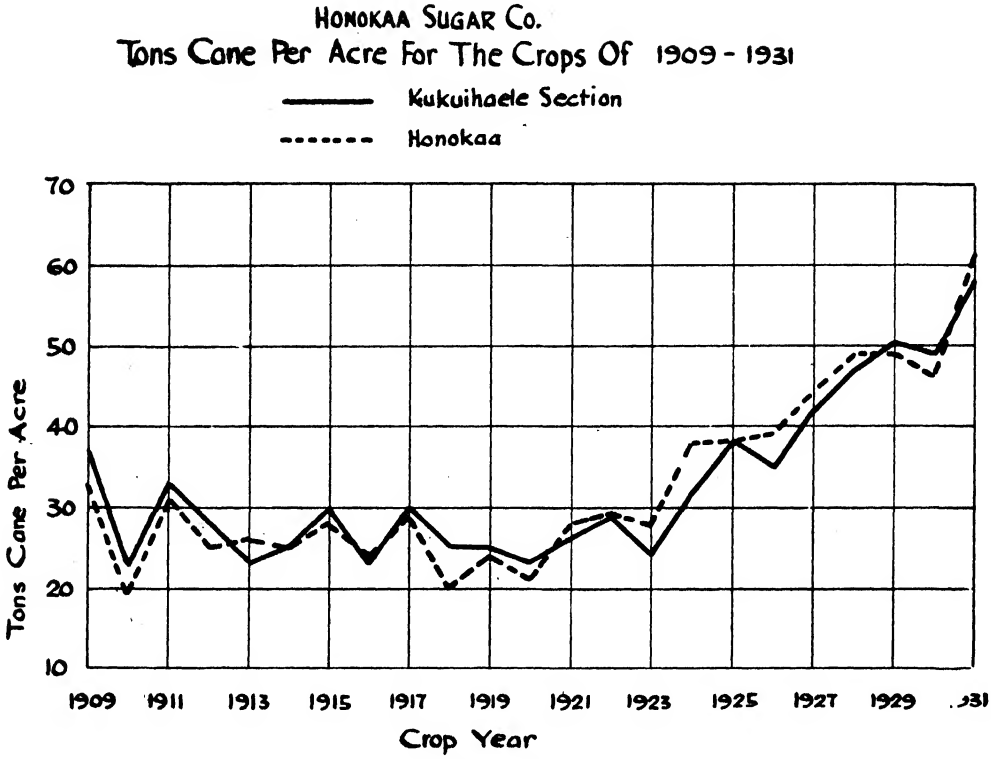


Fig. 1

Honokaa Section fluctuate similarly from year to year. This would naturally suggest that both places are subject to the same influences. The yields are fairly constant up to about 1920, but since then the yields increase progressively. This upward trend in yield since 1920 agrees quite well with a similar trend in yield of the Pepeekeo Sugar Company.

Table II and Fig. 2 show that the yearly fluctuation in yields in the unirrigated section of the plantation (which section should be most subject to weather influences) is similar to the fluctuations in the total area (irrigated and unirrigated) of the plantation. In other words, the irrigated fields have not escaped or overcome those influences that are responsible for the fluctuating yields of the unirrigated section.

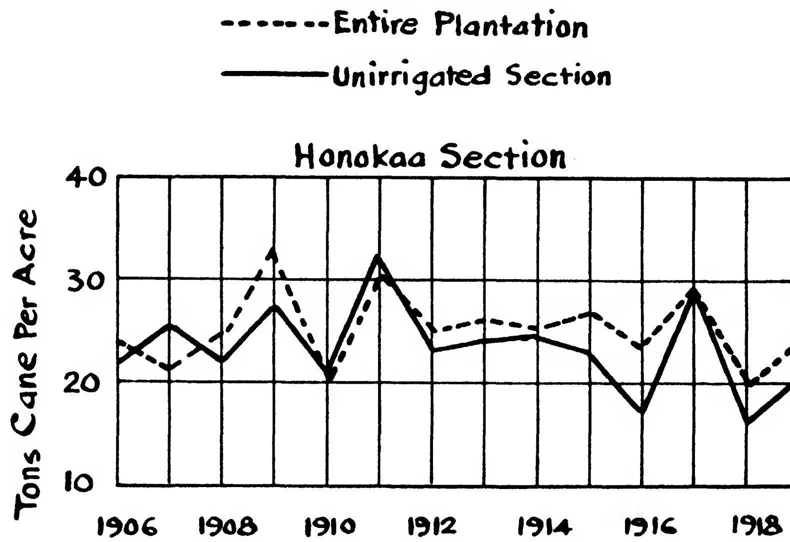
Weather Conditions for the High and the Low Yield Crops

We shall grant that the trend of increase in yield is primarily due to cultural improvements or varietal changes, but how shall we explain the random fluctuations from one year to another? It is not conceivable that the cane yield should suddenly jump 8 or 10 tons to the acre one year and then as suddenly drop 8 or 10 tons, due to some cultural or varietal change, for these changes are never so abrupt on a plantation. Furthermore, these very large fluctuations show that they are brought about by factors over which we have no control. Who of us would like to see the yield drop by 8 or 10 tons of cane if we knew how to prevent it?

We are, then, led to suspect that some uncontrollable factor like the weather is responsible for these sudden rises and drops in yields. Our study of the Hono-

HONOKAA SUGAR CO.

Comparing the Average Yields of Unirrigated Section with the Yield of the Entire Plantation.



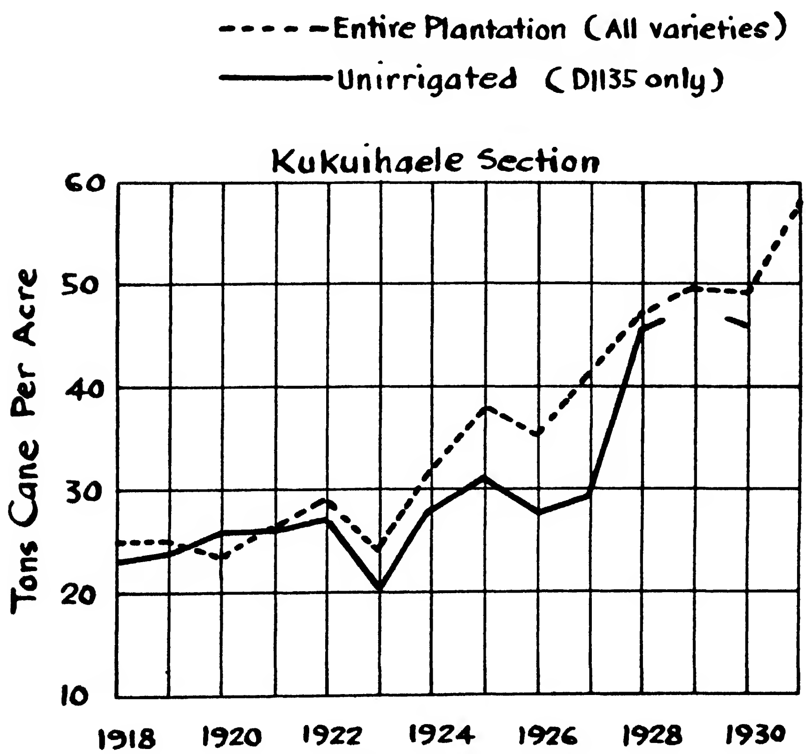


Fig. 2

kaa crop data does show that these random variations are actually the work of weather.

If we take the years prior to 1920, we find that the cane yield was high in 1911 and 1917, that is, there was a sudden increase in yield in these two years as compared with the yield of the years immediately preceding or following. Similarly, the yield was low in 1916 and 1918. How do the weather conditions for the two good crops compare with those for the two poor crops?

Table III and Fig. 3 show that the high yield crops received much more

HONOKAA SUGAR CO.

Comparing the Temperature and Rainfall Conditions for Good and Poor Years.

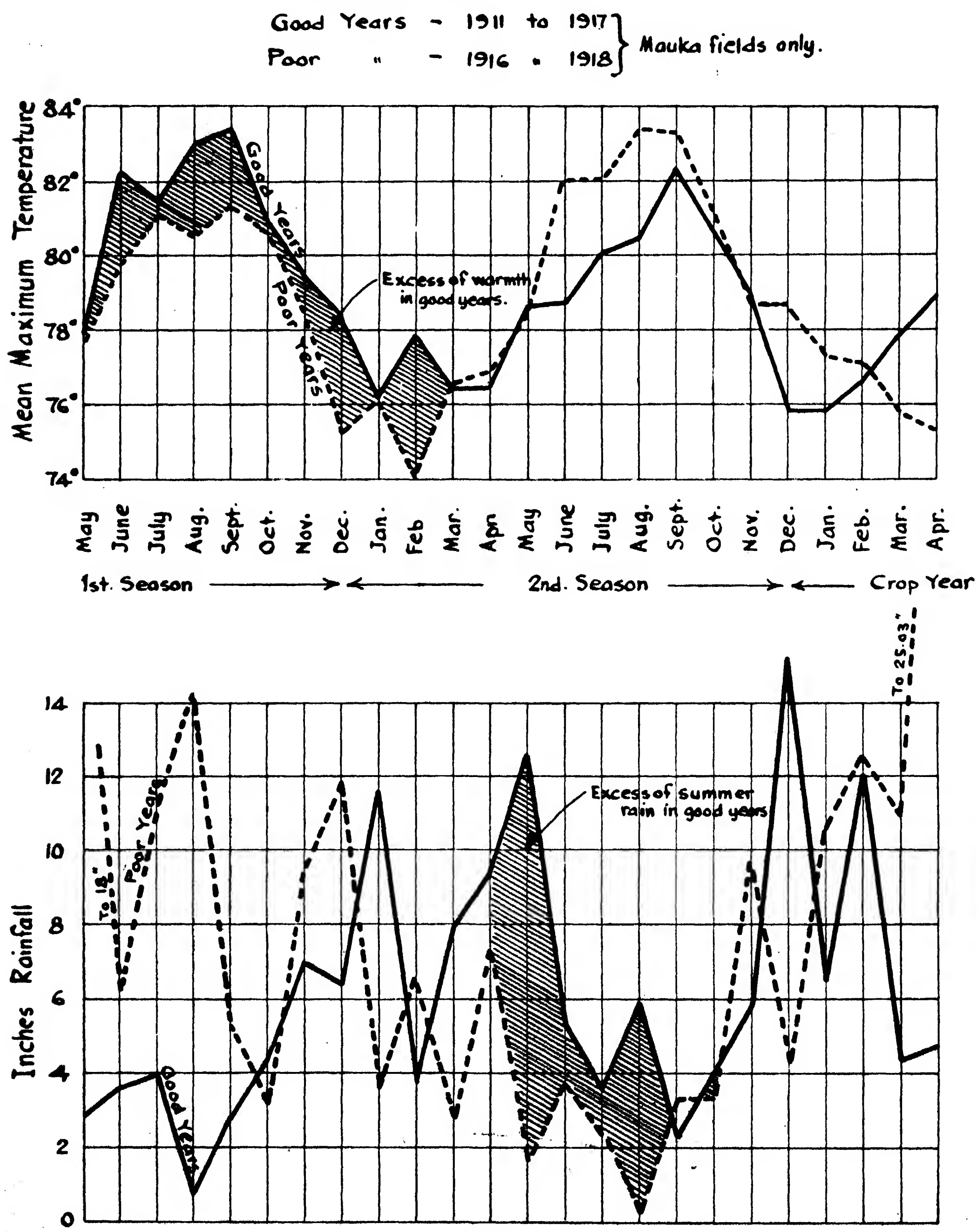


Fig. 3

warmth in the first season of growth than the low yield years. The good crops also received considerably more rain in the spring and summer months of the second season than the poor crops. For high yield, a warm first season would appear to be essential because it is at this period that the foundation of the crop is being laid, it is then that the cane is growing by nature at a rapid rate and therefore can make greater use of warmth.

Also, it appears right that there should be ample water in the second season summer months when the big cane makes increased demand for moisture. Similar differences in weather conditions were found to exist between the high and the low yield crops of Pepeekeo and Ewa.

In studying Fig. 3, one is struck with the fact that it was more in the seasonal distribution than in the total amount of moisture or warmth that the good crops had the advantage of the poor crops. In the good years, warmth and moisture were present when these were needed most. In the poor years, everything came generally at the wrong time.

Temperature Condition in Recent Years

We have seen in Fig. 1 that since about 1920 there has been a progressive increase in the yield of cane at Honokaa. As we stated previously this increasing trend is similar to the one shown by the Pepeekeo yields. In the case of Pepeekeo, we found that the large increases in recent years were due to exceptionally favorable weather conditions. What about Honokaa? Are these large yields due entirely to the progressive changes that have taken place in the agricultural policy of the plantation or do they reflect at least partially the effect of favorable weather?

Fig. 4 is a picture of the temperature conditions at Honokaa for the past 15

Honokaa Sugar Co. (Kukuihaele Station)
Mean Maximum Temperature Expressed as a Plus or Minus Deviation from the 15 yr.-Average.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1916	−	+	−	−	−	−	−	−	−	−	−	−
1917	−	−	−	−	−	−	+	+	+	+	+	+
1918	+	−	−	−	−	−	−	−	−	−	−	−
1919	−	−	−	−	−	−	−	−	−	−	+	−
1920	−	−	−	−	+	+	+	−	−	−	−	−
1921	−	+	o	−	+	+	−	−	−	−	−	−
1922	−	−	−	−	−	+	+	+	−	−	−	+
1923	+	+	+	+	+	−	−	−	−	−	−	−
1924	+	+	+	+	+	+	+	−	−	−	+	−
1925	+	−	+	+	−	−	−	−	−	+	−	−
1926	+	+	−	−	+	+	+	+	−	+	+	−
1927	+	+	+	+	+	+	+	+	+	Data Missing		
1928	+	+	+	+	+	+	+	+	+	+	−	−
1929	+	−	−	+		+		+	+	+	+	+
1930	+	+	+	−	−	+	+	+	+	+	+	+
1931	+	+	+	+	+	+	+	+	+			−
1932	+	−										

Fig. 4

years from 1916 to 1931. The minuses and pluses show for every month of the last 15 years whether the temperature in that particular month was below or above the 15-year average for the month. The recurrence of minuses around 1920 and the preponderance of pluses in recent years lead us to believe that the temperature conditions have been on the whole very favorable in recent years. This is proved more definitely by the tables and figures that follow.

In order to show the total warmth received by each of the recent crops we have utilized the day-degree as a measure of effective warmth. We have assumed that cane grows very little or none at all below a mean maximum temperature of 70° F. We define a day-degree as one degree of temperature above 70° F. for one day. A month, say January, with a mean maximum temperature of 80° F. will, therefore, have 31 x (80-70) or 310 day-degrees.

If we now assume for the sake of simplicity that the average date of starting a crop in Honokaa is May (some fields are started months before and some months afterwards) and also for the sake of simplicity that the average crop length is 24 months reckoned from the day of starting, then we can calculate from the temperature records the accumulated day-degrees for the various crops (assumed, for instance, that the 1931 crop started in May, 1929, and was harvested in April, 1931).

In Table IV and Fig. 5, the accumulated day-degrees for the "odd year" and

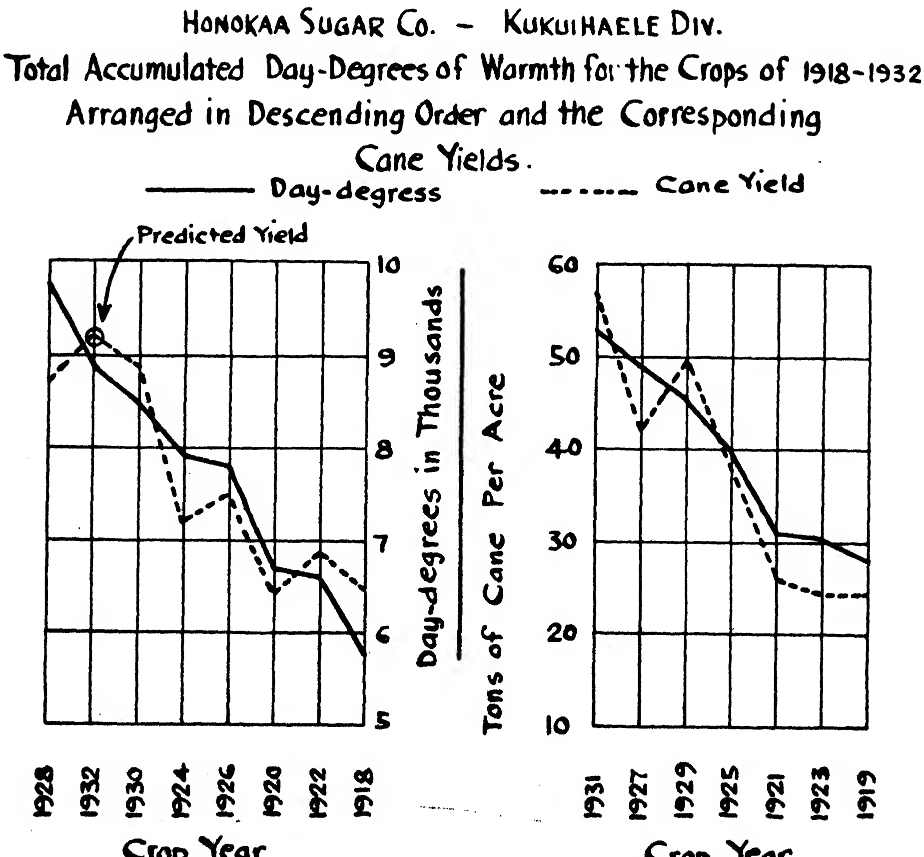


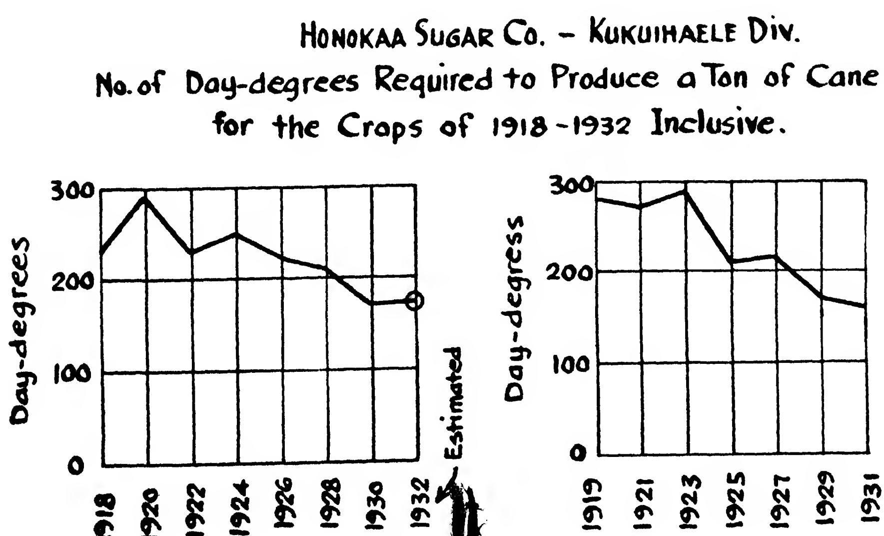
Fig. 5

the "even year" crops are arranged in descending order and the actual yields of cane in the corresponding years plotted against the day-degree figures. The cane yields here shown represent the average yield from all varieties and the entire area of the Kukuihaele section. But as we have seen in Fig. 2, these yields are very similar from year to year to the yields from the Honokaa section. The arguments that we have to offer in this case should, therefore, hold for the whole of the Honokaa plantation.

In Fig. 5, we see a remarkable agreement between total warmth and cane yield. This agreement is still more surprising when it is remembered that the yield figures include all heterogeneous influences such as changes in varieties and in fertilizer and cultural practices. Similar agreements between total warmth and yield have also been found at Pepeekeo. Therefore, there is only one conclusion that we can draw, namely, the influence of temperature is of a preponderating nature on our plantations and that the recent high yields at Honokaa were associated with high temperature. But what about the cultural changes? Are they not reflected in these high yields? We have attempted to answer this question in the following manner.

If we divide the total day-degrees for the various crops by the corresponding cane yield then we obtain comparative figures which show the number of day-degrees required to produce a ton of cane. These "day-degrees per ton of cane" are probably as significant a "measure of the effectiveness of warmth" as the term "gallons of water per ton of sugar" is a measure of the effectiveness of water utilization. Then simultaneously with the improvement in agriculture we should require smaller numbers of day-degrees to produce a ton of cane.

Table V and Fig. 6 do show that Honokaa is getting more tons of cane per day-degree now than it did a few years ago and this we believe is the result of agricultural progress. But this better utilization of warmth alone would not have given these large increases in yields of recent years had not there also obtained a large total of warmth units. Even with the efficiency of 1931, the cane yields in 1919 and 1923 would probably have been poor, because the total amount of heat received by these two latter crops was materially low.



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How do the recent changes in crop length affect the yields? Changes in crop length have taken place mostly in the irrigated section of the plantation; in the unirrigated section the length remains practically the same. Notwithstanding this difference, the recent yields from the unirrigated section show substantial agreement with the yields from the entire plantation. We are, therefore, led to conclude that the changes in crop length that have taken place in some sections of the plantation in recent years have not exercised any influence on yield commensurate with that exercised by the accumulated warmth.

Having now shown that the variations in the yields of recent years are generally associated with conditions of warmth, we can proceed further and show the accumulated warmth for typical high and low yield years month by month from the average date of starting.

In Table VI and Fig. 7 (A and B) are compared the crop conditions of 1928

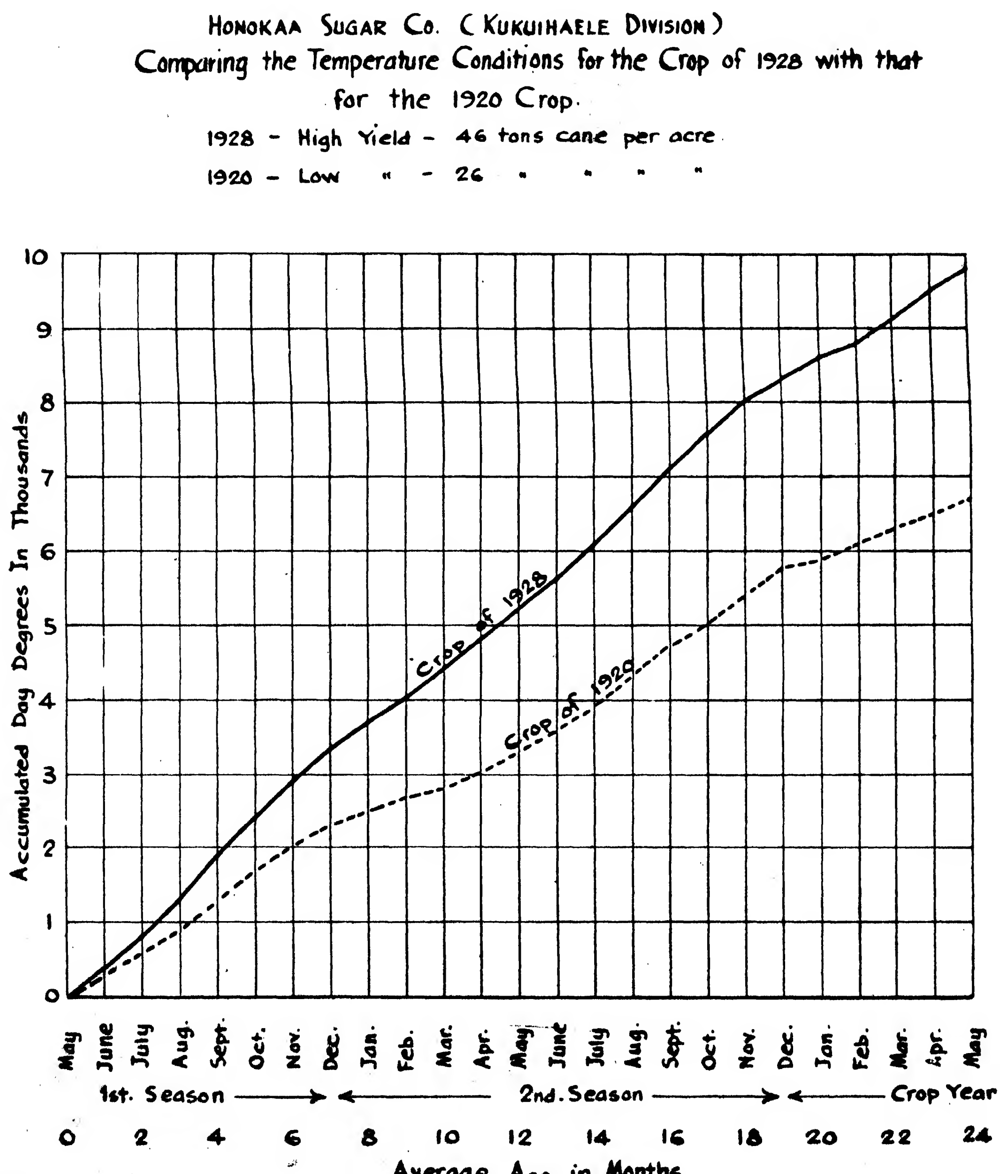


Fig. 7-A

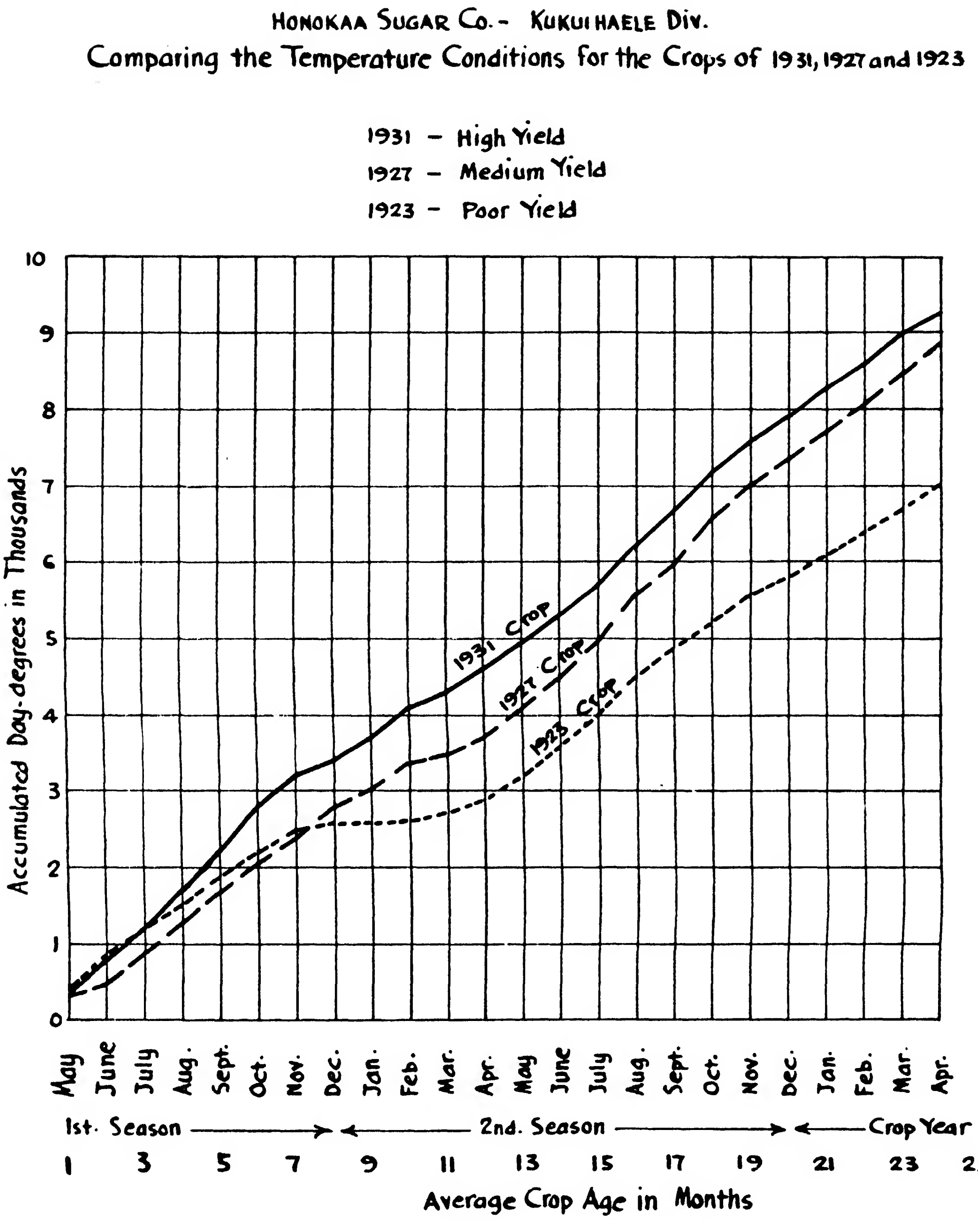


Fig. 7-B

and 1931, high yield years, with the conditions for the low yield years of 1920 and 1923, respectively. The differences in the temperature conditions of the high and low crops are brought out even more strikingly in Fig. 7. At even dates the high yield crops were always ahead of the poor crops by a long margin.

The question may now be raised if we are justified in comparing 1920 with 1928 or 1923 with 1931, for it may be argued that there have been tremendous changes in fertilizer and cultural practices at Honokaa since 1926 and, therefore, the comparison of crops earlier than 1926 with more recent crops is not valid. There was a difference in yield of 20 tons of cane per acre between 1920 and 1928 (same variety in both years). We feel that such a large increase in yield

within the space of a few years could only have been obtained by a combination of favorable factors. It is a fortunate coincidence that together with the big improvements in the cultural policy of the plantation there was also very marked improvement in weather conditions. We find additional support to our view in comparing the conditions for the crops of 1927 and 1931. Both these crops were about equally influenced by recent agricultural changes and they are, therefore, comparable in every respect. The 1927 crop was a fairly good one. The curves in Fig. 7 do show unmistakably that 1927 had better conditions than 1923, but not as good as the conditions for the crop of 1931. The 1931 crop has had the record yield of cane in recent years and we find that it had also the biggest amount of accumulated warmth of any recent odd-year crop.

Similar charts drawn for Pepeekeo and Ewa crops do generally tell the same story. It is our considered opinion that the high yields of recent years were obtained not solely with the help of improved agriculture, but also with the help of exceptionally favorable temperature conditions.

Rainfall Conditions in Recent Years

Table VII and Fig. 8 show the total rainfall in the spring and summer months of the second season for the past 11 crops (Example:—1927 summer rain for the

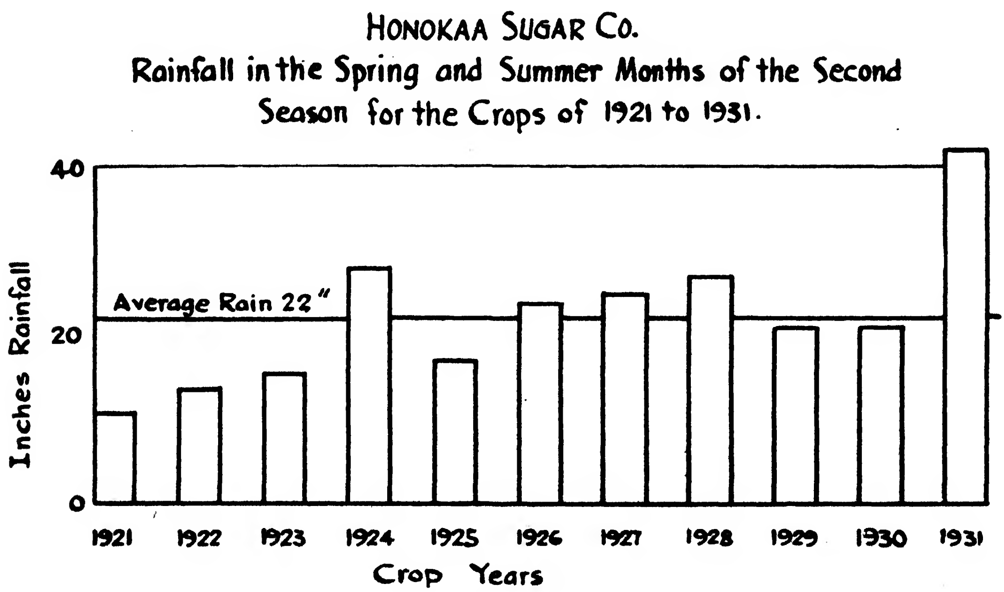


Fig. 8

crop of 1928). We see that the crop of 1931 had almost twice as much rain in the second season spring and summer months as the average for these 11 crops. Therefore, also, as regards rainfall, the 1931 crop was unusually favored. The 1928 crop also had more than average rainfall.

We are, then, justified in concluding that these recent high yields were obtained under very favorable conditions of warmth and moisture. In other words, the good weather made it possible for the plantation to reap the fullest benefit out of

those changes in fertilizer and cultural policies to which alone must be attributed a substantial part of the increased yields.

Rainfall and Juice Quality

In the preceding pages we have shown that the climatic influences on cane yield at Honokaa are the same as at Pepeekeo. Now we shall show that the juice quality is also similarly influenced. (Fig. 9 shows the quality obtained for the crops of 1909 to 1931.)

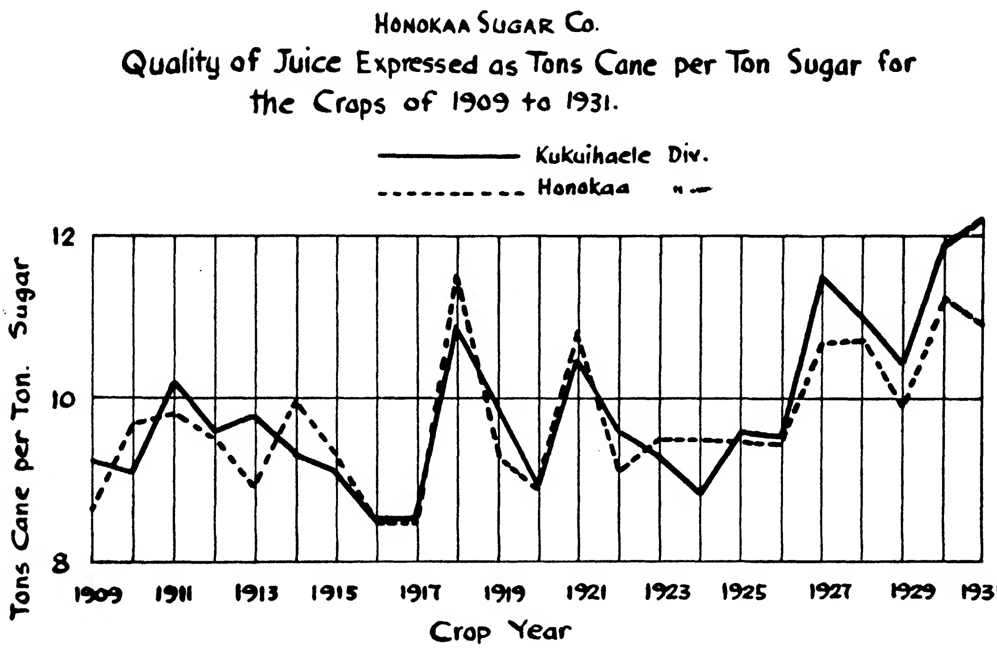


Fig. 9

In our latest study of Pepeekeo we found that juice quality was mainly affected by the seasonal progress of rainfall. In the good juice years the rainfall was ample in the growing months of the second season, gradually decreasing towards harvest time. In the poor years, on the other hand, the second season was dry and the following fall and winter months immoderately wet. In the former case, cane had very likely utilized all easily available nitrogen and completed its vegetative growth by the time it was harvested. In the latter case, vegetative growth might have been arrested by a dry spring and summer. Then, with the advent of a wet fall and winter the cane started belated growth and probably did not reach maturity at the time of harvest.

We find essentially the same picture in comparing the seasonal progress of rainfall for a group of good juice years and a group of poor years at Honokaa. Table VIII and Fig. 10-A show the results.

In the good years the most rainfall was in the second season spring, the harvesting winter had less rain than normal. In the poor years the second season spring and summer were unusually dry and were followed by a wet fall and still wetter winter.

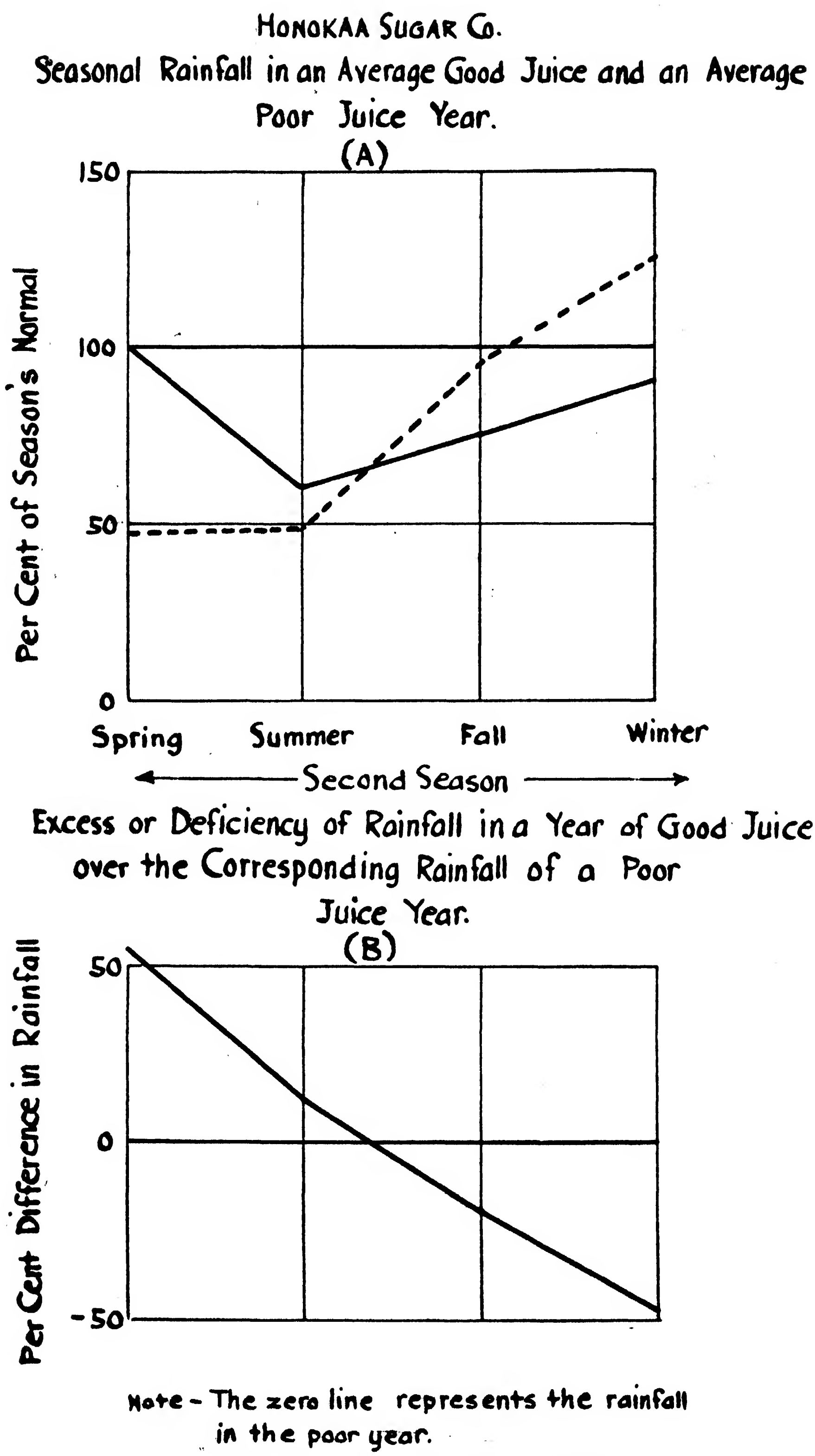


Fig. 10-A. The solid line represents an average good juice year, and the dotted line an average poor juice year.

The difference between a good juice and a poor juice year is further brought out by Fig. 10-B. If the seasonal rainfall for the poor juice year is represented by the zero line, then we see that the good year was wetter in the second season spring and summer when it needed this extra moisture for continuous and active growth and that it was very much drier in the fall and winter months, when this comparative deficiency of moisture was actually conducive to the improvement of juice quality.

Conclusion

This short study supports our previous elaborate studies and further confirms us in our belief that even under the type of conditions represented at Honokaa one can define and measure in general terms the close relation that exists between weather and cane yield.

These series of weather studies bring out very clearly that good and bad weather go in cycles; that while we may justly depend on the good weather to increase our yields we will probably find it difficult to maintain this increase when the bad weather comes.

But what can we do about this weather? We may be asked: How can these weather studies help us to put more sugar in the bag? In reply to this, we may quote from an unpublished report of H. P. Agee:

Of what good is it to measure our crop yields in terms of weather or day-degrees? To this we might answer: Of what good is it to measure yields in terms of acres of land? But all of us are by now so accustomed to think in terms of *tons per acre* that there is no question that land measurement in relation to yields is a substantial aid to the efficiency in crop production. The reason for this is simply because we have learned to use this type of measurement to our purposes.

The irrigation specialists say: The key to water economy is water measurement. Here again we encounter measurement as an aid to efficient progress. In fact all through engineering and scientific affairs generally, we find progress aligned with ability to measure more precisely the resources, materials, or factors that pertain to the things we do.

Hence it is that we offer weather measurement in relation to crop yield, *tons of sugar per 1000 day-degrees*, as a step forward in attaining a better knowledge of our business, a step that will serve us to the degree to which we learn to think and act in terms of this new type of measurement.

TABLE I

HONOKAA SUGAR COMPANY

Cane Yield per Acre from 1909 to 1931

Crop Year	Honokaa T.C.P.A.	Kukuihaele T.C.P.A.
1909	33.1	37.2
1910	19.5	23.3
1911	31.5	33.3
1912	24.9	28.5
1913	26.2	23.4
1914	25.3	25.5
1915	27.6	29.9
1916	24.0	23.4
1917	29.1	30.0
1918	19.8	24.8
1919	23.7	24.6
1920	20.9	23.5
1921	27.7	26.3
1922	29.5	28.9
1923	27.9	24.5
1924	38.0	31.5
1925	38.2	38.0
1926	38.6	35.0
1927	43.7	41.5
1928	48.9	47.0
1929	48.8	49.7
1930	46.2	49.0
1931	60.9	57.7

TABLE II

HONOKAA SUGAR COMPANY

Cane Yields from Unirrigated Sections of Honokaa and Kukuihaele

Honokaa Section (All Var.) Crop Year	T.C.P.A.	Kukuihaele Section (D 1135 Only) Crop Year	T.C.P.A.
1906	22.2	1918	23.4
1907	25.5	1919	24.4
1908	22.2	1920	26.2
1909	27.4	1921	26.1
1910	20.6	1922	27.5
1911	32.3	1923	20.0
1912	23.3	1924	27.5
1913	23.8	1925	31.1
1914	24.6	1926	28.1
1915	23.0	1927	28.7
1916	16.8	1928	46.4
1917	29.3	1929	...
1918	15.8	1930	46.4
1919	20.3	1931	...

TABLE III

Conditions of Temperature and Rainfall for High and Low Yield Crops

Good Years: 1911 and 1917
Poor Years: 1916 and 1918

		Good Years		Poor Years	
		Inches Rainfall	Mean Maximum Temp. F.°	Inches Rainfall	Mean Maximum Temp. F.°
1st Season—	May	2.87	77.9	17.94	77.6
	June	3.71	82.3	6.08	79.8
	July	4.08	81.5	11.02	81.1
	August	.70	83.0	14.21	80.5
	September	2.75	83.4	5.42	81.4
	October	4.15	80.9	3.23	80.6
	November	7.00	79.4	9.44	78.5
	December	6.38	78.4	11.86	75.2
2nd Season—	January	11.65	76.1	3.56	76.1
	February	3.73	77.9	6.49	74.0
	March	6.95	77.4	2.93	76.5
	April	9.33	77.4	7.40	76.9
	May	12.53	78.6	1.86	78.4
	June	5.25	78.7	3.74	82.0
	July	3.46	80.0	2.19	82.1
	August	4.90	80.4	.26	83.4
	September	2.17	82.3	3.25	83.3
	October	3.98	80.7	3.42	81.2
	November	5.87	78.9	9.71	78.7
	December	15.19	75.8	4.23	78.7
Crop Year—	January	6.53	75.8	10.63	77.3
	February	12.02	76.5	12.45	77.1
	March	4.30	77.9	10.82	75.8
	April	4.65	78.9	25.03	75.3

TABLE IV

Accumulated Day-degrees for the Crops of 1918 to 1931

Crop of	Accumulated Day-degrees
1918	5721
1919	6888
1920	6738
1921	7083
1922	6559
1923	7034
1924	7962
1925	7965
1926	7800
1927	8908
1928	9820
1929	8551
1930	8533
1931	9307

TABLE V

Day-degrees per Ton Cane for the Crops of 1918 to 1931

$$\text{Day-degrees per Ton Cane} = \frac{\text{Total Accumulated Day-degrees}}{\text{Tons Cane per Acre}}$$

Crop of	Day-degrees per Ton Cane
1918	231
1919	280
1920	287
1921	269
1922	227
1923	287
1924	253
1925	210
1926	223
1927	215
1928	209
1929	172
1930	174
1931	161

TABLE VI

The Month to Month Progress of Accumulated Warmth for Good and Poor Crops

	"Even Year" Crops		"Odd Year" Crops		
	Good Yield 1928	Poor Yield 1920	Good Yield 1931	Med. Yield 1923	Poor Yield 1927
1st Season—					
May	384	251	329	372	270
June	828	551	800	783	543
July	1336	883	1200	1161	896
August	1860	1264	1727	1518	1262
September	2355	1660	2243	1863	1694
October	2876	2035	2776	2229	2134
November	3305	2338	3169	2478	2437
December	3674	2518	3439	2627	2809
2nd Season—					
January	4024	2673	3740	2627	3048
February	4416	2841	4054	2627	3378
March	4835	3039	4349	2680	3530
April	5216	3285	4586	2929	3692
May	5638	3561	4912	3227	4076
June	6091	3897	5281	3590	4520
July	6593	4272	5743	4040	5028
August	7123	4653	6193	4471	5552
September	7591	5022	6697	4855	6047
October	8003	5419	7202	5246	6568
November	8321	5758	7616	5561	6997
December	8569	5885	7948	5849	7368
Crop Year—					
January	884[illegible]	6074	8298	6119	7716
February	9097	6287	8620	6385	8108
March	9469	6513	9001	6701	8527
April	9820	6738	9307	7034	8908

TABLE VII

Total Rainfall in the Spring and Summer Months for the Crops of 1921 to 1931

Crop of	Total Rainfall in Inches
1921	11.19
1922	13.75
1923	14.38
1924	28.28
1925	17.51
1926	24.15
1927	24.52
1928	27.33
1929	20.95
1930	21.28
1931	42.16

Average for (1921 to 1931) = 22.3 inches.

TABLE VIII

HONOKAA SECTION—HONOKAA SUGAR COMPANY

Seasonal Progress of Rainfall in a Group of Good and a Group of Poor Juice Years—Rainfall Expressed as Percentage of the Season's Normal.

Good Years—1916, 1917, 1920, 1929
Poor Years—1914, 1918, 1921, 1930

2nd Season—	Good Years	Poor Years	Difference Good Year-Poor Year
Spring	101%	47%	+ 54%
Summer	61	48	+ 13
Fall	77	96	— 19
Winter	93	127	— 34

Plant Wilt and Its Relation to the Rates of Water Supply and Water Demand

By H. A. Wadsworth

That the physical symptoms of wilt are the results of insufficient moisture in the leaves and stem of a plant goes without saying. And yet some of the reasons for these symptoms are not self evident.

As everyone knows, moisture is lost from the leaves of a plant by transpiration while water is added to the leaves by the translocation of soil moisture from the soil to the aerial plant parts. The many ingenious and complicated hypotheses, which have been developed to explain this translocation of moisture from soil to leaves, need not concern us. At best it can only be said that the process is not fully understood.

Be that as it may, the fact remains that water is continuously being lost from the leaves and continuously being replaced. The question of rates is at once apparent and deserves most serious consideration if a true understanding is desired.

For illustration, let it be supposed that a mature cane plant is being grown in nutrient solution or tap water after the manner of Dr. Lyon's spectacular experiment. Here the supply of "soil?" moisture is limitless and of equal availability throughout the life of the plant. The *rate* at which water may be moved from the reservoir, however, is not at all without a finite limit. Every drop of water removed from the solution must be absorbed by the roots, surely a process which takes some time, and conveyed against the resistance to flow in the minute tubes of the vascular system within the cane stick. In any hydraulic system the conveyance of water takes time. The analogy between the tracheids in the stick and a bundle of minute pipes may be far-fetched but it seems to be physically sound.*

From this reasoning one might suppose then that in the conditions of Dr. Lyon's experiment, water should be abundantly available in the leaves of the cane regardless of the demand upon the leaves for water until a certain maximum demand was reached. If the conditions of the environment such as excessive light and heat demanded a greater supply than this maximum, water would be lost from the stored water in the leaf tissue, the familiar symptoms of wilt being evident. Under such conditions we would have cane evidencing all the symptoms of wilt although growing in nutrient solution.

Here the question of rates is of most importance. The rate at which water is required for transpiration in any given plant depends upon the intensity of sunlight, the temperature, the relative humidity and, to a minor extent, upon wind velocity, while the rate at which water is available to the leaves depends upon the number of absorbing roots and the hydraulic characteristics of the conveyance

* A recent thesis at Stanford was devoted to "The hydraulics of sap."

system. Naturally, if the rate of loss from the leaves exceeds the rate of supply, flaccid tissue must result and plants exhibiting flaccid tissue are said to be wilted.

It is doubtful if a cane plant growing in the environment of Honolulu and in a nutrient solution would ever exhibit the customary signs of wilt due to this difference in rates.* The character of the vascular system indicates a great capacity for water conveyance, while Dr. Lyon's photographs show an amazing development of absorbing roots. Moreover, the cane leaf is peculiar in its ability to retain its form and apparent turgor.

It is apparent that "wilt" from the hypothetical conditions suggested above is quite temporary and will disappear when conditions so adjust themselves that the demand for water from the leaves is less than the potential supply from the vascular system. The setting of the sun with the resulting lowering of temperature and an increase in relative humidity ordinarily restores complete turgor when temporary wilt has been experienced. Examples of temporary wilt are quite common elsewhere; the most spectacular being the behavior of the apricot tree in the Santa Clara Valley in California during the heat of the summer. In many cases the trees show every sign of vigor by crisp, normally held leaves until the middle of the afternoon when all appearances of wilt become evident. Recovery usually takes place at sundown. And this process may continue during the hottest months, although the orchard may be continuously and abundantly irrigated.

Wilt of this type is naturally called "temporary wilt" and depends upon the relation between the demand for water, by the factors making for transpiration, and the rate at which water may be supplied by the roots and vascular system. The relative soil-moisture content at the time of wilt does not need consideration since such wilt may occur at any soil-moisture content. Although temporary wilt may not be common in cane fields in Hawaii, and we have little evidence on the point, the conception of temporary wilt is stressed here to emphasize the point that a question of rates is involved.

When observations are made upon a plant rooted in soil other complications are added. Water is no longer available in limitless amounts as in the case of water culture because as is well known a soil may be too dry to permit normal turgor and we say once more that the plant is wilted. The conception of rates again applies but in this case wilt may be caused not by a temporarily excessive demand from the leaves but by an insufficient rate of supply. And this insufficient rate of supply is due to the fact that whatever moisture may still be in the soil, is so tightly held to the soil grains that it can be torn loose and absorbed at only a very slow rate. Wilt of this type is called "permanent wilt." Permanent wilt can only be corrected by adding water to the soil. By so doing one increases the rate at which water is made available to the roots and consequently to the leaves.

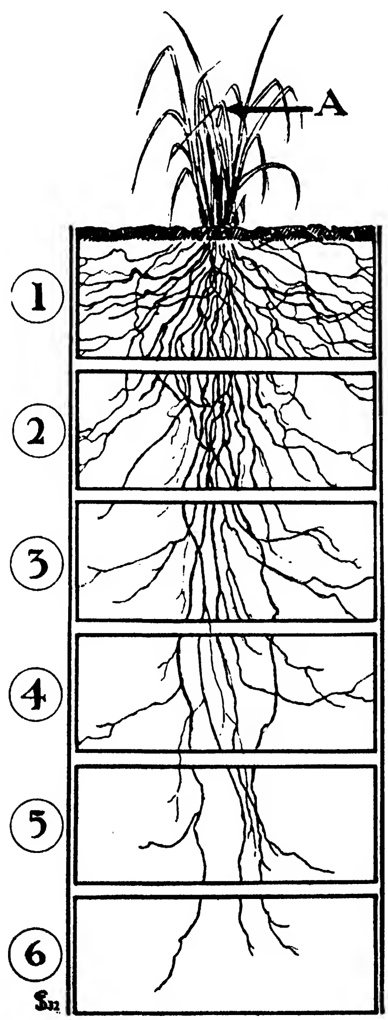
Since both temporary and permanent wilt are indicated by the same symptoms, it is necessary to distinguish carefully between them. Temporary wilt has already been described. An arbitrary definition holds that a plant suffers from permanent wilt when that plant fails to recover turgidity within twelve hours when the loss of water from the leaves is essentially reduced to zero. As indicated above, this

* Wilt symptoms were observed in one of the water culture plants grown by H. L. Lyon.

condition may be brought about by placing the plant in the dark, by lowering the temperature and by increasing the relative humidity.

The argument is simple enough if plants are grown in containers that are small enough, in view of the expected root spread, to permit complete root permeation. In such a case, every cubic inch of soil would be invaded by feeding roots in about equal abundance. Consequently, one would expect different points within the soil mass to reach the moisture content at which water is insufficiently available at about the same time. A large part of the work involving the conception of permanent wilting has been done with potted plants.

When plants grown in the field are considered, no such complete permeation of roots is possible. Some plants are characterized by deep roots, while others are surface feeders. Nor from an inspection of the root distribution as evidenced by trenches cut across the rows would one expect that every cubic inch of soil was invaded by a feeding root. Moreover, although most of the roots of a cane plant in the field are to be found in the upper two feet, significant amounts may be found in the third and relatively smaller numbers in the fourth, fifth and perhaps sixth foot.



This distribution is diagramatically shown in the illustration. If the entire soil mass is wet at the beginning of observations, every active root in the entire depth is a potential source of supply and the rate of supply is, as in the case of the water culture, determined by the total number of roots and the hydraulics of the vascular system.

The rate at which water is being lost from the leaves seems to be determined entirely by environment. For example, some evidence leads us to believe that a mature cane plant transpires about 15 pounds of water per day under the conditions of the dry side of Oahu. Let it still further be supposed that this loss of 15 pounds per day is uniform throughout the 24-hour period. Everyone who has worked with cane knows that this is not the case and that transpiration is much greater during the day than during the night. But the supposition of uniform transpiration makes a logical step in the reasoning.

Under the conditions, then, water is being lost at *A* in the diagram at a rate of 15 pounds per day, this amount being taken from the soil invaded by the roots. It may also be assumed that the rate of loss from each foot in the diagram is about proportional to the number of roots in each. Consequently, if the diagram represents anything like the truth, most of the 15 pounds would come from the first two feet, much less from the third, and so on.

If the soil as shown in the diagram is uniform, the first two feet contain no more soil moisture than the next two, and yet moisture is being lost from them at a rapid rate due to the heavy root concentration. At some time a day will come when the soil moisture in the first two feet will be so far reduced that the roots in this zone cannot contribute their normal quota to the 15 pounds required daily, and the demand upon the roots in the third foot will be increased. Here, however, the root distribution is scanty and although ample soil moisture would be available by vigorous root extension in this stratum, the cane plant seems to prefer to suffer than to modify its normal rooting habit. Consequently, the lower depths fail to meet the added demand for water because of the exhaustion of available moisture in the surface two feet. The demand of 15 pounds per day continues; the available rate of supply is less than this amount for reasons which have been given; plant tissues become flaccid. Since growth either by cell division or cell enlargement cannot occur with flaccid tissue, growth ceases. Nor can growth be resumed until such a percentage of the soil mass has been supplied with water, that the roots within it can deliver water to the leaves at our hypothetical rate of 15 pounds per day.

If one secures samples for soil-moisture determination in the first two feet in the diagram, the soil-moisture content at the time of growth cessation should be approximately equal to the percentage of moisture in the soil at the time of wilt as determined by the use of potted plants in the same soil. This may primarily be due to the fact that the cane plant seems to carry a compact root system. If the roots spread thinly through large areas and to great depths, an insufficient rate of supply of moisture might be evidenced at a high average soil-moisture content as determined by soil sampling. For in this case, a given soil sample might contain a large amount of soil that had not been depleted by root action. Although it would not be generally supposed that fruit tree roots completely invade every

cubic inch of soil, such must be essentially the case for much evidence indicates that such trees as apricots and prunes exhibit signs of permanent wilt when the soil moisture, as determined by field samples, approaches the figure indicative of permanent wilt with potted plants grown in similar soil.

In San Diego County, orange groves are frequently irrigated on the basis of results from soil-moisture determinations. An irrigation is ordered when the average soil moisture percentage in the upper three feet of soil falls dangerously near the permanent wilting percentage.

The argument so far advanced has been based upon the conception that the transpirational demands are constant during the 24-hour period. Evidently this conception is not in accord with the facts and the argument should be re-examined in view of the fact that transpiration during the night is practically zero and may approach 2 or 3 pounds per hour for a mature stool during the heat of the day.

If we again use the diagram as an illustration, the loss by transpiration at *A* becomes a variable and may range from zero, to, say, 2 pounds per hour. At high moisture contents all the soil strata hold their maximum amounts and the rate of supply in view of the activity of all the roots is sufficient to satisfy the peak demands of the afternoon. Consequently, growth is continuous during day and night. It is evident, however, that a time will come when the rate of supply, in view of the inevitable depletion of moisture in the more heavily rooted depths, will be insufficient for the periods of peak demand, although sufficient for the periods of darkness. Under such conditions of extreme differences between day and night temperatures, one might expect growth to be continuous and uniform during periods of high moisture content for in that case full turgidity might be expected. At lower moisture contents, say, when the rate of supply by the roots was sufficient to maintain turgor during the night but not during the day, one might expect elongation during the night and curtailed growth during the day. And at still lower moisture contents the period of darkness may be too short to allow for the full recovery of the flaccid tissue of the preceding afternoon. Consequently, no growth during either day or night could be expected.

It should not be thought from this discussion that the only loss occurring from wilting plants is a loss of potential growing time. Sometimes a condition of wilt at a particular stage of growth sets up a resulting effect which greatly reduces yields. This point has been most completely explored with cotton. If this crop is allowed to experience wilt at the time the bolls are forming, an abnormally great dropping of partly matured cotton bolls may be expected. Any such possibility with sugar cane is not recognized at present.

Summary

1. This paper is free from detailed results of experimental data. It purports to be no more than a discussion of some of the factors involved in the wilting of plants, particularly sugar cane.

2. Wilt is described as the natural result of a loss of water from the plant at a greater rate than the rate of supply of water from the soil.

3. The same conception of rates seems to apply to both temporary and permanent wilt. An attempt is made to differentiate between them.

4. Since wilt is a sign of flaccid tissue and since cane plants characterized by flaccid tissue cannot elongate normally, if at all, the practical value of precautions against wilt is evident.

5. Although an ample supply of soil moisture may be available in the third and fourth and fifth foot of soil, the cane plant apparently prefers to wilt and eventually die than to modify its normal rooting habit by developing extensive root systems in these lower strata.

The Hilo Forest Reserve

By L. W. Bryan
Forest Supervisor

Foreword

The following report covers the work accomplished in the Hilo Forest Reserve during the past ten years by Forestry Unit No. 3 in cooperation with the Territorial Division of Forestry. The work of the unit is so thoroughly interwoven with that of the Territorial Division of Forestry that it is impossible to segregate the activities of one from the other, and no attempt will be made to do so in this report.

Organization

Forestry Unit No. 3, which embraces all of the area known as the Hilo Forest Reserve, was organized in 1921 by the plantations on the Hilo coast, which interests have since maintained it. This reserve includes both government and private lands, about 60 per cent of the area being owned by the government, while the remainder is controlled by the plantations concerned.

In our work, little attention has been paid to the ownership of the various lands, the object always being to carry through to completion whatever work was necessary for the good of the reserve as a whole, regardless of where this work had to be done.

All work in the Hilo Forest Reserve is done under the supervision of the writer, who acts as forest supervisor for the unit and, at the same time, directs the work authorized by the Territorial Division of Forestry.

Four ranger stations are maintained in this reserve and one forest ranger, one nurseryman and four tree planters are regularly employed. In addition, during the slack season, the plantations usually put on, for such periods as they can be spared, a number of extra men who plant trees and do other forestry work.

There is now in operation 15 miles of telephone line connecting the various stations and many miles of trails are maintained within, and adjacent to, the reserve area. Telephones and trails are of vital importance to the reserve. They are not only essential for routine procedure but, in cases of emergency such as forest fires, they are indispensable. Both must always be in running order and constant care and attention are required to keep them so.

Five rain gauges and two temperature recording stations are maintained within the reserve. Records obtained therefrom have already proven of value.

In the land of Honomu, within the forest reserve, a small park, embracing the area around Akaka Falls in the Kolekole Gulch, has been developed. Akaka is the highest waterfall on the Hilo coast, having a sheer drop of 418 feet. It may be reached by trail from the end of a new automobile road. This park has been

improved principally through the efforts of the Hononu Sugar Company and constant care is necessary to keep the grass cut and the paths clear. This area is very popular with tourists and is also well patronized by local people. A small house and fireplace have been constructed at a vantage point overlooking these falls.

Survey

One of the first steps undertaken was to secure a survey and map of this reserve, for, previous to 1921, this area had never been entirely marked out on the ground. The survey, which was carried through by the Territorial Survey Department, assisted by Unit No. 3, and which required about six months to complete, showed that this reserve embraced an area of 111,750 acres, making it the largest in the Territory. Since 1921, several additions have been made, bringing the total area up to 122,782 acres.

This reserve, which covers a strip about 30 miles long with an average width of 10 miles, extends, unbroken, from the land of Waiakea on the south to the Hilo-Hamakua boundary line on the north. The lower or makai line follows near the 1,700-foot contour and the upper or mauka boundary is above 5,000 feet.

While the boundary survey was being made, considerable data were secured concerning such matters as existing trails, trespass of cattle, areas in need of planting, etc., etc. All of this information was used in the preparation of a status map, showing the condition of each land within, and adjacent to, the reserve.

Fencing

During the course of the survey work, it was discovered that in several places, stock was being permitted to trespass within the reserve, so immediate steps were taken to secure protection against this nuisance by constructing several miles of new fence. A considerable part of this fencing was accomplished with the cooperation of owners of adjacent lands. During the period covered by this report, 23 miles of new fence have been built and fences previously constructed have been kept in repair. There is now a total boundary length of 90 miles, 56 miles of which are protected by stock-proof fences. All fences are gone over at least once a month, for constant patrol and frequent inspections are necessary if this area is to be kept in a stock-free condition.

Animals

After fencing, it was found that a considerable population of wild or semi-wild animals still inhabited the reserve. In order to rid this area of them, it was found necessary to shoot all those that could not be removed by other means. During the past ten years, there have been reported as killed within this reserve 89 head of wild cattle, 1155 wild pigs and 88 wild goats. There will always be a few wild cattle but they have been reduced to such a small number that they now do very little damage. Pigs do not seem to be nearly as plentiful as in former years, but they still do some damage in certain sections. Goats are only found on, or adjacent

to, the lava flows on the southern end of this area. These animals fortunately do not like the thick, wet jungle and seldom enter except along the outer edges in extremely dry weather.

Trees

Tree planting was commenced during the latter part of the first year and has continued ever since. Up to date, we have planted out 927,063 trees on, or adjacent to, this reserve and in addition have supplied and supervised the planting of 20,979 trees for windbreaks along the seacoast. We have also furnished many thousands of fruit and ornamental trees which have been planted out on plantation lands.

At the start, very little was known regarding just what species of trees were suited to a given area and mistakes were unavoidably made. In order to try and determine which species were best suited to a given locality, a number of arboreta were established at different locations. These arboreta were carefully laid out, mapped and an accurate record kept of the different species planted therein. Up to date, we have experimented in this way with nearly 500 species. Many of them have proven to be unsuited for our work and have been discarded, while others show considerable promise. Those which have shown up to best advantage in our arboreta are being planted out in considerable numbers in our regular reforestation work.

In our plantings within the reserve, our aim has been to introduce species that would eventually spread themselves and, of course, at the same time, provide a suitable watershed covering. Among other trees, several members of the genus Ficus have been used with success. Many of them have now reached fruiting size and from those that produce fertile seed (*Ficus macrophylla* and *F. rubiginosa*), we can soon expect natural reproduction to become evident. Other species, such as *Ficus nota*, are now fruiting but their pollinating wasps are not present so it will be impossible for them to spread naturally until such a time as the proper wasps have been introduced.

In our plantings below the reserve area, we have tried to employ such trees as can some day be utilized by the plantations for fuel, lumber and the many other uses where wood is indicated. Several different kinds of timbers are now being tested as fence posts, some treated and some untreated. Some of the trees planted for utility purposes, during the early part of the period covered by this report have now reached a size sufficiently large to be cut and many of them are already being used for fence posts, firewood, flume props, etc.

In the camp areas, the planting of fruit trees has been encouraged in the hope that the fruit which they will some day supply may prove a valuable addition to the laborers' diet.

Whenever possible, assistance has been rendered in the beautification of parks, camps, mill grounds, residential premises, roadsides, etc. In several cases, formal planting plans have been prepared and the necessary planting material furnished to execute them.

At the start, a survey showed that there were about 16,000 acres within the Hilo Reserve in need of reforestation. This does not mean that all of this area

must be planted by hand for, in some sections, the native forest is coming back of its own accord and, as already stated, we may reasonably expect a certain amount of natural reproduction by species already planted.

Planting along the mauka boundary of this reserve has presented an entirely different problem from that which we found makai. The mauka boundary is over 5,000 feet in elevation and has less rainfall than is found at most of our lower levels. Many different species have been tried in this section, a few of which have proven successful. The rate of growth is slow, due to cold nights throughout the year. Several species of temperate zone trees do well but have the disadvantage of being deciduous, losing their foliage during the winter months. We have much to learn regarding what is best to plant in our mauka lands and are going about the solving of this problem in a cautious manner. We do not propose to plant out large numbers of any given species until, through actual trial, it has proven to be what we want. It is encouraging to note that in several sections of our mauka lands, the native koa (*Acacia koa*) has given good results and in some areas has come back naturally.

The plantings made by Puu Oo Ranch, in the mauka section under the requirements of their leases with the different plantations, have proven of value in an experimental way. They have planted out 14,000 trees representing 52 different species. From these plantings, we have gained considerable knowledge regarding the habits and possible value of the species tested.

Three tree nurseries directly connected with this unit have been established and continuously operated. One is maintained by the unit at our Nauhi Gulch Station at 5,100 feet in the land of Honohina. Here are raised trees for planting in the mauka lands and, conditions being different, we have been forced to adopt methods somewhat different from those employed in the low lands. This nursery and station is entirely a unit project. The other two nurseries have been independently maintained by the Hilo Sugar Company and Honomu Sugar Company, respectively.

The Territory maintains a nursery in Hilo. At the start, it was apparent that this nursery, with its then small force and meager appropriations, could not begin to supply the unit's demand for planting material. In order to be assured of a steady supply of trees to meet our needs, the unit employed two additional men and placed them in this nursery. This arrangement proved satisfactory and through it we have secured adequate planting material.

During the period covered by this report, there have been raised and shipped 2,119,599 plants from these four nurseries divided as follows:

Hilo Nursery (Government)	1,876,175
Nauhi Gulch	19,062
Honomu	91,747
Hilo Sugar Co.	132,615
Total	2,119,599

In addition to the nursery work at Nauhi Gulch Station, we have experimented with a large number of plants among which have been some 60 different varieties of temperate-zone fruit trees. Several of the latter are now producing fruit which

appears to be at least equal to that imported from the mainland. Our experiments would seem to indicate that this mauka country is well suited to the cultivation of such fruits as apples, pears, quinces, plums, cherries, etc., and there is sufficient area available to produce enough fruit of the kinds named to supply all island markets. Propagating material has been secured from some of the most promising of these trees and about 2,000 young plants have been rooted and distributed.

Proper planting methods and care of young trees after planting has been one of our important problems and it is only by experimentation that we have achieved a technique that seems satisfactory. We do not strive to plant out a large number of trees in order to make a showing. Rather we lean in the opposite direction and plant out new trees only after those previously planted have been cared for. A recent impartial check of some of our older plantings showed that nearly 90 per cent of those planted were alive.

As one method of reforestation, we have tried direct broadcasting of certain species of trees but with only a small degree of success. Occasionally, we find trees growing as a result of our efforts but they are not common except in cases where a seed-bed has been first prepared for certain rapid-growing species. Airplane sowing of seed has not been tried in this reserve. However, on an adjacent reserve considerable success has been attained by employing this method.

Law Enforcement

When we first started in to fence our boundaries, we found many cases of flagrant violations of our forestry laws and rules, mostly due to ignorance. Warnings were issued, forest signs posted, and people in general educated and informed regarding the laws and, as a result, violations have become less numerous. At present, we have only an occasional illicit pig hunter to deal with. During the past ten years, we have had occasion to make thirty-six arrests, all of which resulted in conviction. The law governing the removal of tame stock from a forest reserve (Section 586, R. L. of H., 1925), has been invoked several times and $194.50 collected in fines. This money is paid into a special Territorial fund which is used for forestry purposes.

Forest Fires

This reserve has been very fortunate in not having had any real serious forest fires. Only once during the past ten years has it been seriously threatened. Pumps and other fire-fighting equipment are maintained by the Territory at the Hilo Nursery and are available at all times. District fire wardens always respond promptly with necessary men and equipment in case of fire and the infrequency of serious forest fires can be attributed to their prompt action, for a fire is easily controlled if reached in the early stages.

Along the lower edge of this reserve there are large areas of uluhi fern that constitute a serious fire menace. In these areas, we are attempting to reduce this hazard by first cutting lanes or paths through the fern and then planting out rapid-growing species of trees and caring for them until the trees "top" the fern. We hope that they will eventually shade out the uluhi.

By using succulent species of trees and other plants that are not inflammable, the fire hazard can be reduced. Most species of Ficus are very difficult to burn on account of the nature of their sap-wood. The use of succulents, as a means to prevent forest fires, is receiving considerable attention on the mainland and results obtained are very satisfactory.

Future Work

Tree planting has been one of our principal activities in the past and should continue to receive a considerable part of our attention in the future. New species should be tried in our different arboreta; useful species such as can be used for timber, fuel, fruit, windbreaks, etc., should be planted out in suitable areas below the actual reserve line and species of proven value should be added to our watershed area. Nursery work should continue along the same lines as heretofore in order to furnish suitable planting material for our needs.

We should continue to protect our reserve area by keeping up our fences and continuing our campaign against injurious animals.

Fire hazards should be reduced wherever possible and our fire plan revised from time to time as need requires. An effort should be made to secure a portable gasoline fire-pump and hose line for use in areas where water is available. Water is probably the most satisfactory agent with which to combat forest fires.

Rain gauge and temperature recording stations should be continued and, perhaps, new ones added. It might prove advisable for the unit to undertake the securing of stream-gauge records on some of the more important streams in this reserve.

Our knowledge of the interior of this reserve is still limited. An airplane map of the entire reserve would prove of immense value. Such a map would at once disclose all open areas regarding many of which we have no knowledge at present. It is recommended that an effort be made to secure a map of this nature.

Summary

During the past 10 years, the following work has been accomplished in the Hilo Forest Reserve:

1. The reserve has been surveyed and additions made where necessary.

2. A working organization has been perfected.

3. Trees totalling 948,042 have been planted out in, or adjacent to, this reserve.

4. Twenty-three miles of new fence have been constructed, and fences previously built have been maintained.

5. Fifty-six miles of fence have ~~been~~ regularly patrolled and kept in repair.

6. A total of 1,332 wild animals has been reported killed.

7. Forestry rules and laws have been strictly enforced.

8. Transportation and communication lines have been maintained and increased where needed.

9. Fire hazard has been practically eliminated in this reserve.

10. The closest possible cooperation has been maintained at all times between Unit No. 3 and the Territorial Division of Forestry.

Fig. 1. Motojiro Sadaiki, tree planter, *par excellence*, employed since 1921 by Honomu Sugar Company to plant trees. In 10 years, this man has planted out and cared for over 212,000 trees. We offer this as a record of achievement along these lines, particularly as a high percentage of these trees are alive today.

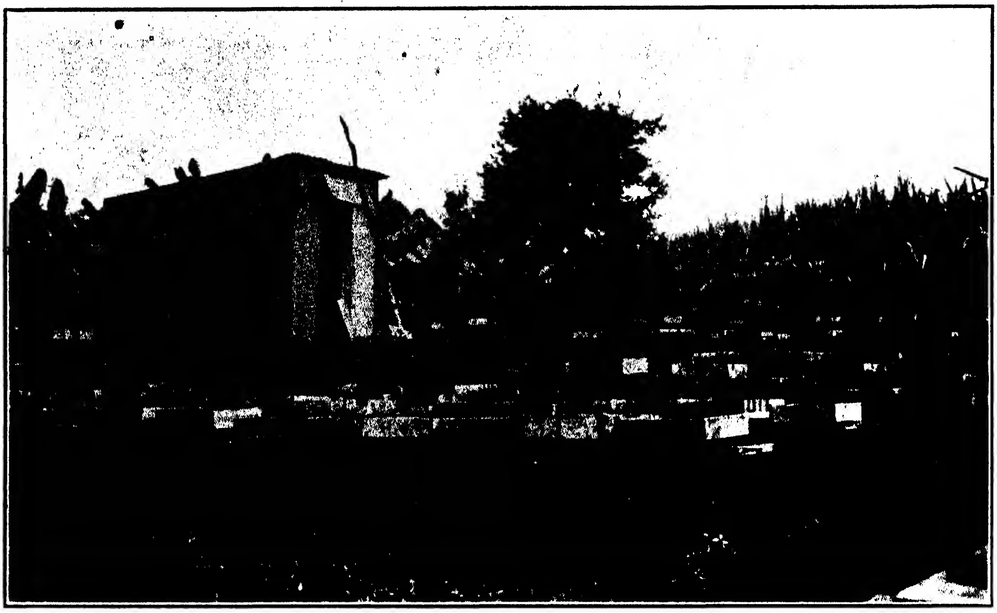


Fig. 2. Honomu Sugar Company's nursery. In addition to his tree-planting work, Motojiro Sadaiki has raised many thousands of plants in this nursery.

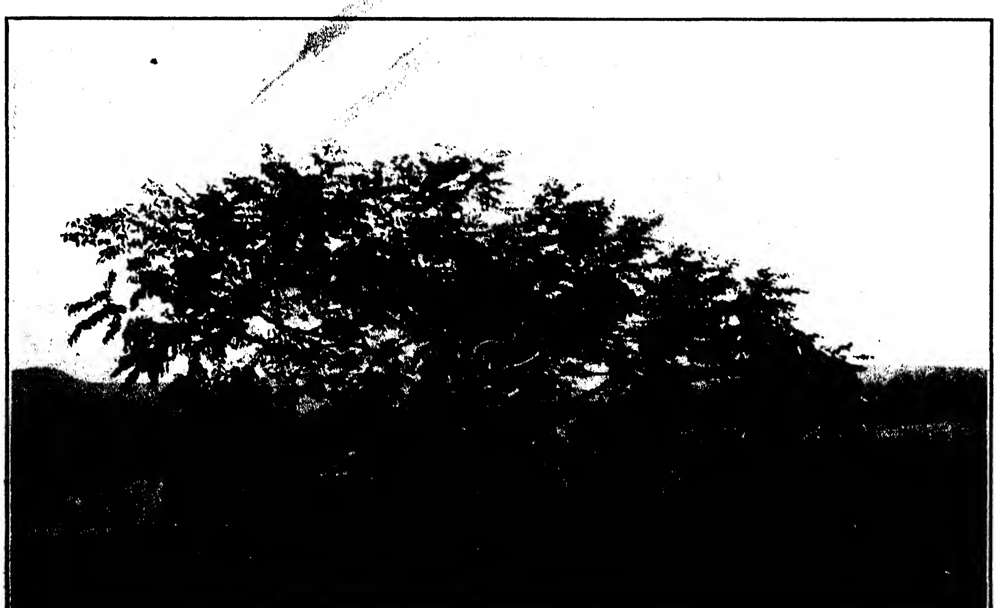


Fig. 3. *Trema orientalis*, 8 years old, 23 feet high, Pepeekeo Arboretum.

Fig. 4. *Albizzia stipulata*, 2 years old, 15 feet high. This is one of the best species of Albizzia that we have planted out on this island. Pepeekeo Aboretum.

Fig. 5. *Tristania conferta,* only 10 months old, 5 feet high. This species is doing well in our plantings from sea-level up to 5,000 feet elevation. It produces valuable timber and is one of our best trees for general planting. Pepeekeo Arboretum.

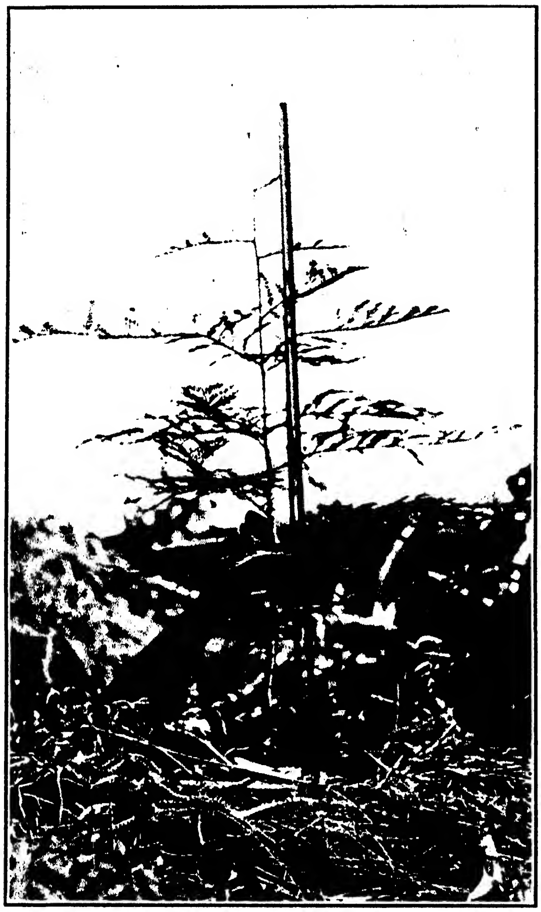


Fig. 6. *Sequoia sempervirens*, 2 years old, 4 feet high. This is the tree which produces the redwood of commerce. It is doing well in several sections of this island. Trees planted out in 1927 are now over 20 feet high. Pepeekeo Arboretum.

Fig. 7. *Angophora lanceolata,* 2 years old, 10 feet high; a relative of the eucalyptus, and is very promising. Pepeekeo Arboretum.

Fig. 8. *Podocarpus cupressina*, 8 years old, 21 feet high. Pepeekeo Arboretum.

Fig. 9. *Terminalia myriocarpa,* 8 years old, 40 feet high. This is one of the best trees that we have yet planted out. It is doing well up to 5,000 feet elevation. It is native to India, reaches a large size and produces valuable timber. Pepeekeo Aboretum.

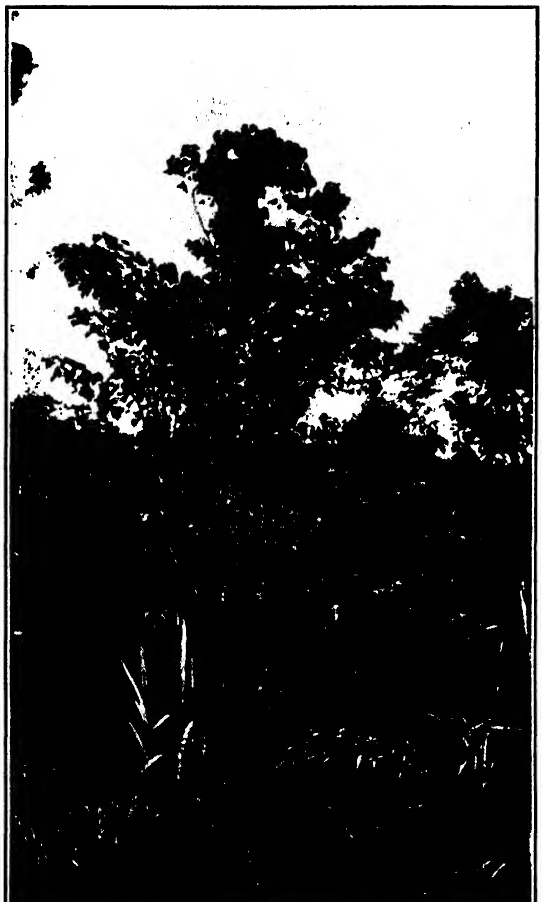


Fig. 10. *Heliocarpus americanus*, 7 years old, 30 feet high. Pepeekeo Arboretum.

Fig. 11. *Leptospermum gracilis*, 8 years old, 18 feet high. A large bush or small tree. Grows in very wet locations. Pepeekeo Arboretum.

Fig. 12. *Vitex parviflora*, 8 years old, 12 feet high. A slow-growing tree, producing a very hard wood. Pepeekeo Arboretum.

Fig. 13. *Camphora officinalis*, 7 years old, 11 feet high. Pepeekeo Arboretum.

Fig. 14. *Lagerstroemia speciosa*, 7 years old, 9 feet high. Pepeekeo Arboretum.

Fig. 15. *Terminalia myriocarpa* and *Melaleuca leucadendron*, 3 years old, land of Kamaee.

Fig. 16. *Eucalyptus robusta,* 3 years old, growing in very wet area, land of Kamaee.

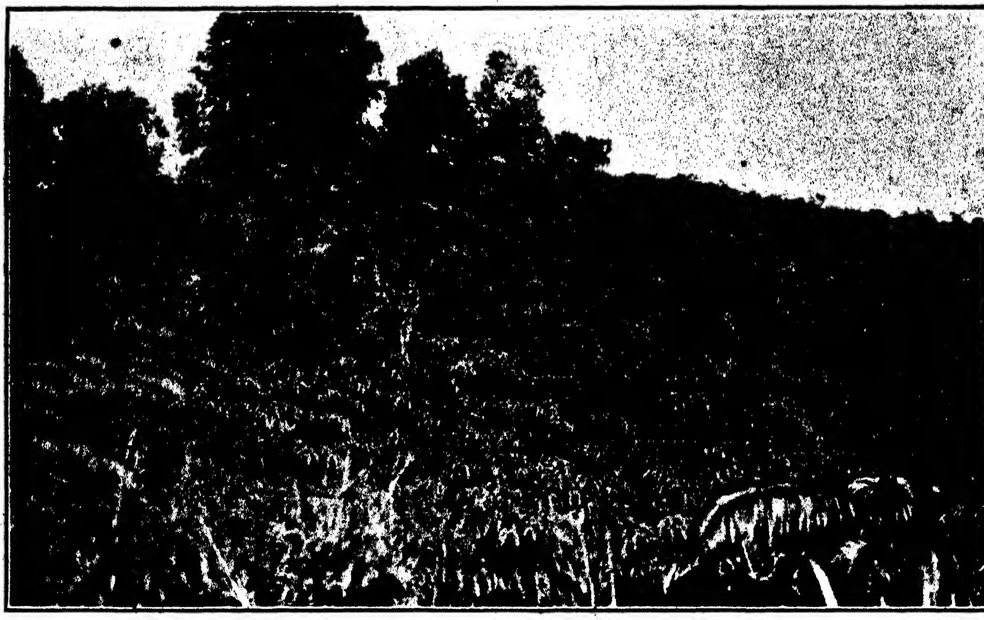


Fig. 17. Showing heavy growth of uluhi fern along the lower edge of the forest reserve in the land of Kamaee. This pest has taken hold of large areas and is very difficult to plant trees in. It is a serious forest-fire menace and one of our problems is to find a means of getting rid of it and finding something more suitable to take its place.

Fig. 18. Another area of uluhi fern that has been planted up with *Eucalyptus robusta*. Our best method of control seems to be to clear paths or lanes through this fern and plant fast-growing species of trees that will eventually shade it out. The young trees in the picture can just be seen. After one more cleaning, they should be able to care for themselves.

Fig. 19. *Cryptomeria japonica* growing in uluhi fern area. This tree is too slow in rate of growth to successfully compete with this fern.

Fig. 20. *Taxodium mucronatum*, land of Hakalau-nui, 7 years old. This species is very slow in growth but eventually makes a good tree and produces good wood.

Fig. 21. *Eucalyptus rostrata,* 7 years old, land of Haka-lau-nui.

Fig. 22. *Cupressus arizonica*, 5,700 feet elevation, 6 years old, land of Laupahoehoe.

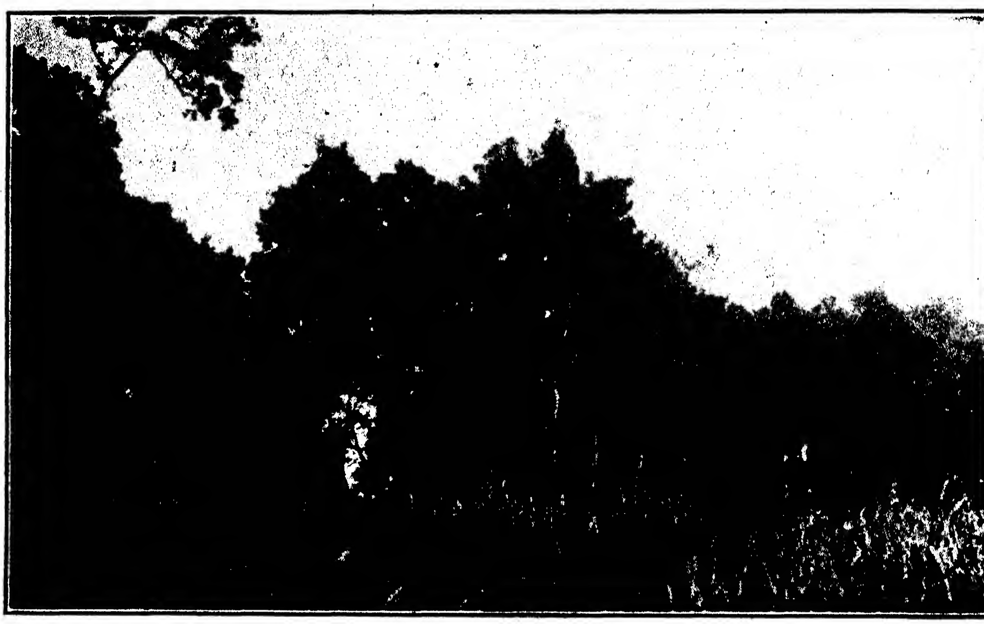


Fig. 23. Natural reproduction of *Acacia koa.* Cattle were removed from this area about 12 years ago and since then considerable native koa has come in and grown to good size. Land of Piha, elevation 5,500 feet.

Fig. 24. Nauhi Gulch Station. Here, we maintain our mauka nursery for the handling of plants suited to higher elevation. Land of Honohina, elevation 5,100 feet.

Fig. 25. Grove of mixed Eucalyptus, 8 years old, planted out by Puu Oo Ranch in mauka Makahanaloa under their lease agreement with Pepeekeo Sugar Company.

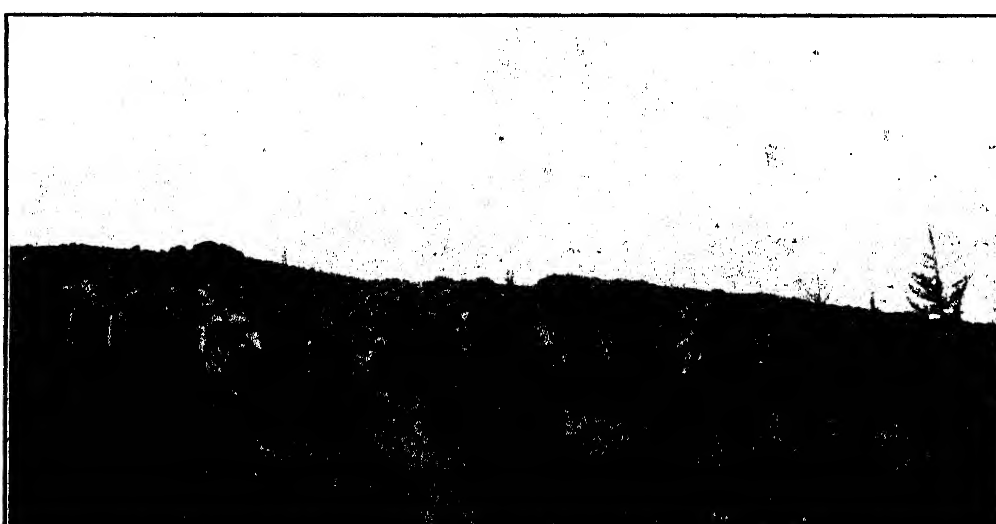


Fig. 26. *Cryptomeria japonica*, 6 years old, planted out by Puu Oo Ranch in mauka Papaikou under their lease agreement with Onomea Sugar Company.

Fig. 27. Hybrid plum, 3 years old, at Nauhi Gulch. We have planted out over sixty different varieties of fruit trees at this station. Many of them show every sign of success.

Fig. 28. *Platanus occidentalis*, 2 years old, land of Piha, 5,400 feet elevation.

Fig. 29. *Catalpa* sp., 2 years old, land of Piha, 5,400 feet elevation.

Fig. 30. Grove of *Heliocarpus americanus*, 3 years old, land of Puueo.

Fig. 31. Grove of *Cedrela australis*, 3 years old, land of Puueo.

Fig. 32. *Jacaranda mimosaefolia,* 3 years old, land of Honomu.

Fig. 33. *Cedrela australis*, 3 years old, growing in uluhi fern, land of Puueo.

Fig. 34. *Fraxinus* sp., 3 years old. This tree has done well with us in all of our plantings from sea-level to 5,000 feet elevation. Land of Honomu.

Fig. 35. Native forest growth in the land of Laupahoehoe. Some of the finest native forest can yet be found in the northern end of this reserve.

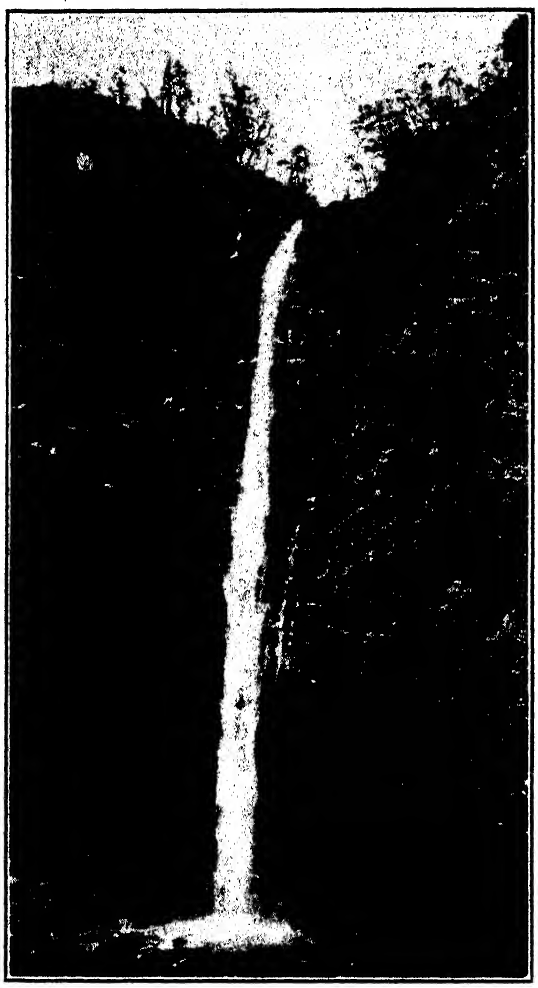


Fig. 36. Akaka Falls, highest waterfall on the Hilo coast. The area around this fall is within the reserve and is treated as a park and recreation area. It is very popular with tourists as well as with local people.

Fig. 37. *Ficus rubiginosa*, 6 years old. This is the first tree of this species to produce fertile seed on this island. The wasp has, of course, become established and we can soon expect natural seedlings. Land of Piihonua.

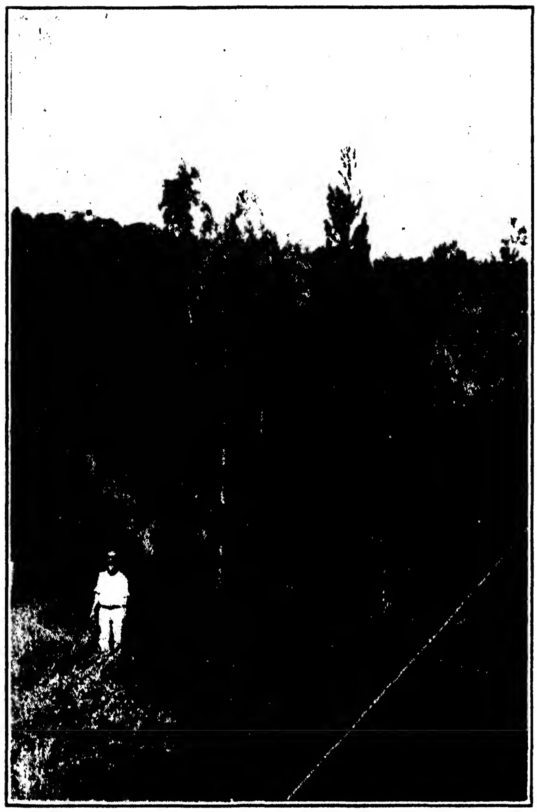


Fig. 38. *Cryptomeria japonica,* 7 years old. This tree produced a good grade of wood and does well in our very wet soils. The location where this photo was taken has an average rainfall of 233 inches per annum. Land of Piihonua.

Fig. 39. *Ficus nota*, 6 years old. This species grows best in shaded places. Land of Piihonua.

Fig. 40. Mixed planting of *Eucalyptus rostrata*, *Fraxinus* sp. and *Cupressus macrocarpa*, 6 years old. Land of Piihonua.

Fig. 41. *Ficus nota in fruit.* The wasp for this species has not yet been introduced from the Philippines. Land of Piihonua.

Fig. 42. *Monstera deliciosa*, 6 years old. A number of these aroids have become established along the gulch sides in this section. Land of, Piihonua.

Fig. 43. Indian fire pumps in use. These pumps are most useful for "mopping up" work and a number of them are kept on hand at the Hilo Nursery and ready for use at all times, together with other fire-fighting equipment. Every plantation would, undoubtedly, find a number of these pumps a good investment.

Fig. 44. *Eugenia cumingii*, 7 years old, in foreground. The trees in the background are 20-year-old *Eucalyptus robusta*. For very wet locations, this tree does as well as any we have tried. Pepeekeo Arboretum.

Plantation Interval Tests

By H. R. Shaw

The interval test, a type of irrigation field experiment, has proved of direct value to many plantations. These studies on the relation of time of application to cane yield have contributed to a knowledge of plant and water relations and of the most desirable irrigation policies. The chief value of the interval test has been to provide a "short cut" which, otherwise, might require years of experience by the "trial and error" method.

A completely reliable method of determining the proper distribution of irrigation waters to plantation fields is an exceedingly difficult problem to solve. Soil variation, the distribution and movement of soil moisture, and the growth of the cane plant as related to the involved and ungovernable factors of sunshine, light, and natural precipitation form variables whose effect is even more pronounced in irrigation experiments than in many other types of investigation.

In 1923, the agricultural department of the Ewa Plantation Company developed the interval test in an effort to obtain results which might be applied directly and profitably to field conditions. The interval between irrigations to adjacent plots, rather than the quantity of water, was varied, and the assumption tacitly made that the irrigator employs essentially the same amount of water during the course of an irrigation.

"Under one's own local conditions, the chief way to control irrigation is through regulation of the interval," W. P. Alexander, former agriculturist of the Ewa Plantation Company, points out. "One can't tell a water luna to apply 5 acre-inches of water per month, but one can issue orders to irrigate the cane every 15 days on the assumption that each irrigation will supply 2.5 acre-inches. It is for this reason, if none other, that the interval test offers a practical method of finding out the proper use of water and of being able to apply these data in a practical manner."

The area irrigated by one level ditch was taken as the plot unit in the interval test. The plot area was necessarily large, seldom being less than one acre, and frequently ranging as high as 4 acres in size.

In each experiment, three irrigation treatments were usually compared. By a *maximum* treatment, the cane received frequent irrigations at a rate more rapid than was popularly considered to be practical with the irrigation methods and available water supply in use; a *normal* treatment supplied the cane with adequate irrigations as based on the best conditions, from the standpoint of water and labor supply, that the plantation could offer; and by a *minimum* treatment, irrigations were made as seldom as possible without allowing the cane to die. A fourth treatment, plantation practice or check, by which irrigation water was applied at the same interval as that to the surrounding field, was occasionally added.

Due to the size of the plots, three replications of each treatment arranged in series or in "checkerboard" fashion were all that could be maintained profitably.

Thus, each test consisted of from 9 to 12 level-ditch plots usually covering a total area of from 9 to 40 acres.

The interval between irrigations to each plot series was determined somewhat arbitrarily by past experience and collateral investigation. No particular effort was made to control the amount of water applied during each irrigation as the difficulties of such refinement in field experimentation with sugar cane are great unless a disproportionate degree of supervision is given. In a majority of the experiments, water to each plot was measured at the entrance to the level ditch by means of a submerged orifice installation supplemented by a portable mechanical meter. Rectangular weirs and Parshall flumes were used for the measurement of water to the experiments of the Pioneer Mill Company.

The plan of the interval test seemed to answer many of the requirements of a comparatively simple and direct means of irrigation investigations. Level-ditch plots large enough to permit a normal and consistent supply of water, reduced the lateral movement of water between plots to a minimum, and provided natural boundaries for the harvesters. The simplicity of the method appeared to require little more than routine attention and supervision for satisfactory results, and there seemed every indication that the results might be of direct and profitable value to the plantation.

Following the inauguration and initial success of the interval test at Ewa Plantation Company, similar investigations were installed on other plantations with varying success. Perhaps the largest and most ambitious of these projects was that sponsored by the American Factors, Ltd., on three of its Kauai plantations, Koloa Sugar Company, Lihue Plantation Company, and Makee Sugar Company. There, however, difficulties which were not apparent under the relatively constant water supply and equable climate of Ewa, confronted the investigators, and the conduct and interpretation of the tests was a much harder task.

The irrigation supply of the three plantations is almost entirely dependent upon mountain rainfall and, with the exception of the Koloa plantation, which has a considerable reservoir reserve, the supply may fluctuate greatly throughout the year. Rainfall, always a difficult factor to evaluate, is comparatively heavy on this portion of Kauai, and the steeper slope of the land necessitates even greater care in the installation and operation of water-measuring devices than is the case on the level Ewa terrain. During periods of drought, with which the Kauai plantations are frequently afflicted, it has often been impossible to maintain even the minimum irrigation treatment. The prevalence of rat damage and of eye spot and other pathological diseases added further complications to the tests.

Disadvantages of the Interval Test

Although large experimental plots may have an advantage in the smooth-running routine of a plantation, they frequently prove disastrous in the conduct and subsequent interpretation of an experiment. Few localities in the Hawaiian Islands have so uniform a soil that, in a large experimental area, the error due to soil variation will not exert a profound influence. The limited number of replications prevent statistical scrutiny of the results, and serve mainly to indicate

major deviations between plots of the same treatment. The arithmetical average of the results from the three plots of a series frequently deviates so greatly from any one of the individuals that its true value is debatable.

The nature of the physical and moisture-holding properties of the soil undoubtedly has a major influence on the amount and time of irrigation applications. Many plantations using interval tests have attempted roughly to classify certain areas of their estates according to soil type as determined by structure or as affected by prevailing weather conditions, and arbitrarily to assign the interval between irrigations to each plot based on the results of experience in that area. Such classifications, although probably necessary as a first departure, do not take into account the gradation of one soil type into another, the variation in moisture-holding properties of the soil, nor the local variation in climate over comparatively small and restricted areas.

One of the greatest dangers connected with the conduct of interval tests is the fallacy that a fixed interval between irrigations may be maintained throughout a crop without regard to the effect of seasonal variation on water consumption and cane growth. Although many plantations have recognized this factor and have attempted, by the use of detailed growth measurements in each plot, to evaluate the effect of seasonal variation on the growth of sugar cane, the yearly differences in temperature, rainfall, hours of sunshine, and similar factors may be great enough to limit the value of the results. This danger has sometimes been overlooked or neglected, and the same interval maintained throughout the crop.

"I feel that the seasonal effect of irrigation intervals should be further investigated, particularly in cane that is above waist high," writes K. B. Tester, assistant manager of Pioneer Mill Company. "In young cane one has to do weeding and the oftener he gets around with irrigations, the cleaner the field. In larger cane, however, the weeding question does not come in."

Closely allied with the problem of seasonal variation on irrigation intervals is that influenced by the age of the cane. Certainly it is logical to expect that as the foliar growth and the root system of the plant develop, the draft of moisture from the soil will increase manifold; yet, with few exceptions, this factor has not been considered in most interval tests. The age of cane also exerts an influence on the surface distribution of water. As the cane approaches maturity and as obstructions to the stream caused by recumbent cane, leaves, and trash increase, the assumption that essentially the same amount of water is used in each irrigation may, and probably does, vary from the truth. Hence, if we may consider that the quantity of water used increases with the age of cane, the two variables of time and quantity enter the experiment at each successive irrigation.

The type of crop may also exert an influence on the irrigation interval. Young plant cane requires frequent irrigations to provide rapid germination and growth; on the other hand, ratoon cane is apparently able to thrive for some time without irrigation provided that water is applied immediately after harvest. As cane is successively ratooned, the physical condition of the field often becomes poor, furrows and ditches are silted until their capacities are greatly reduced, watercourses are eroded, and the surface soil is packed and compressed. Thus, it

would seem logical that the interval between irrigations should be more frequent than that to plant or young ratoon fields, and that the results of tests on old ratoons might be affected significantly by surface conditions.

"It seems that a plant or young ratoon crop gets the water where it is wanted," Mr. Tester comments. "Often the physical condition of an older ratoon makes the use of water wasteful. Although water measurements generally show that old ratoons use more water, a large amount of this is probably lost. At Pioneer Mill Company, the plant fields take much less water per round than do the ratoons. I feel that the physical condition of the field is about as large a factor as anything in determining the amount of water applied."

An intangible factor, but one important in the successful conduct of an interval test, is the attitude of the labor toward it. Not infrequenly the irrigator considers that a comparison of "plantation practice" with other irrigation treatments is an implied reflection on his standard of work. The reaction often has been to favor plots under such practice over those receiving other treatments and to justify his methods by special care and attention.

Results of Typical Interval Tests

The application of experimental results to the irrigation routine of Ewa Plantation Company has been thoroughly discussed in previous papers by members of the plantation staff. Interval tests at Ewa have led to the conclusion that the first irrigation to ratoon cane should be applied immediately after harvest, that frequent irrigations are not needed for very young ratoons, and that cane between the ages of 3 to 11 months exhibits the greatest response to optimum irrigation and fertilization. It has also been established at Ewa that cane over 11 months of age does not respond to frequent irrigations, and that the interval should be gradually extended in the "pre-maturity" stage—from 14 months of age to within 40 to 80 days of harvest.

Through the courtesy of the Koloa Sugar Company, Lihue Plantation Company, and Pioneer Mill Company a summary of the results from typical interval tests harvested for the crops of 1927 to 1931 has been prepared. The data are presented in terms of acre-inches of water applied for the crop and in average yields of tons cane and tons sugar per acre. Unless otherwise noted, H 109 is the cane variety grown in each test, and water has been applied by the standard contour system of irrigation.

The majority of the interval tests on these plantations point decisively toward the beneficial results accruing from frequent applications of water. The frequency of irrigations indicated by the results of these experiments was not always obtainable under the methods of irrigation and the water and labor supply then existing. The results of interval tests on the plantation of the Koloa Sugar Company are directly responsible for the development and extension of the "Koloa System" of irrigation by which it has been possible to irrigate the same area with more than double the previous frequency without an increase of labor or water supply. J. T. Moir, Jr., manager of Koloa Sugar Company, writes, "Our whole present practice of irrigation is predicated on the general results of the tests run

here. We were sufficiently convinced that a faster, lighter irrigation would be productive of increased yields of cane and sugar. Our recent results seem to have justified our conclusions." The increased frequency between irrigation applications is also an outstanding feature of the border method of irrigation which has been developed and extended in Hawaii since 1926.

The interval test may prove of much value by indicating the relationship between frequency of irrigations and yield in areas previously not under cultivation or in which a definite and concrete irrigation policy founded by long experience has not been established. Tests on many plantations have demonstrated that regularly planned and scheduled intervals between irrigations result in increased cane yields. Evidence from these and other experiments indicates that a distinct depression of growth may result from over-irrigation, particularly on wet, poorly drained soils.

Case I—Koloa Sugar Company—"Dry" Fields

The series of interval tests represented in Fig. 1 were conducted on plantation fields at a low elevation and which receive a relatively small annual rainfall.

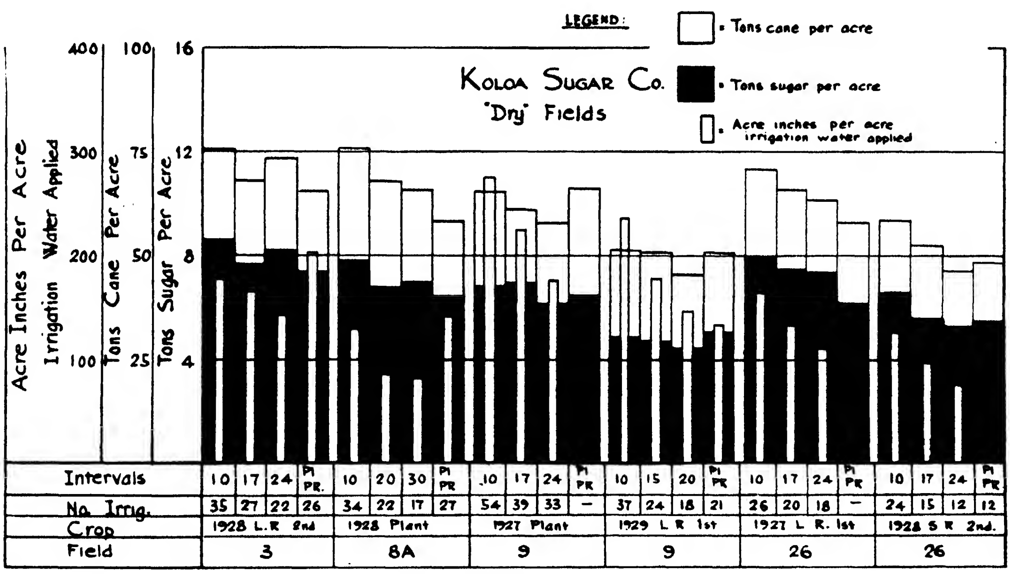


Fig. 1

A casual inspection of the data as presented in Fig. 1 intimates a proportional relationship between amount of water applied and final yields of cane and sugar. The descending order of cane yield and irrigation water for each treatment is especially marked in Fields 8-A and 26 for both the 1927 and 1928 crops. Differences in cane ratios cause the proportion between water applied and yield in tons sugar per acre to be less apparent, but in at least four of the cases, increased yields of sugar resulted from the maximum treatment. The fact that the two factors of time and of quantity of irrigation applications are involved leads to the question as to whether the greater amounts of water or the greater rapidity of successive applications resulted in the increased yields. In view of our present

knowledge of plant and water relations, it seems probable that the frequency of applications rather than the total amount of water applied was the factor instrumental in the increased yields of the first treatment. Comparison of results, especially on the basis of tons sugar, between the normal and minimum treatments of the experiments in this series, is difficult, and the differences are apparently insignificant. The plantation practice showed a decrease in yield with a greater consumption of water over all other treatments in Fields 3 and 8-A of the 1928 crop and in Field 26 of the 1927 crop, a slight increase in cane yield over all other treatments in Field 9 of the 1927 crop, and no significant difference between treatments in Field 9 of the 1929 crop.

In many of the cases reported in this paper a specific irrigation treatment apparently causes a commanding difference in tons cane per acre over other treatments, but lower juice quality results in no significant difference in the yields as based on tons sugar per acre. Mr. Alexander comments on this factor as follows: "I am impressed with the depressing effect of the extra water on the sucrose content. This might merit a special study of its own. In so many of these tests the cane yield due to the frequent waterings was counteracted by a higher quality ratio. This brings up the question of how the cane was irrigated in the last stages of the crop. With less water then, the results might have been different. It was found at Ewa that an analysis of the quality ratio was not enough; the Brix and purity were bigger factors to study."

Case II—Koloa Sugar Company—"Medium" Fields

The series of experiments represented in Fig. 2 are situated in the central belt of the plantation at an elevation of 100-300 feet, and receive a normal rainfall of 60 inches.

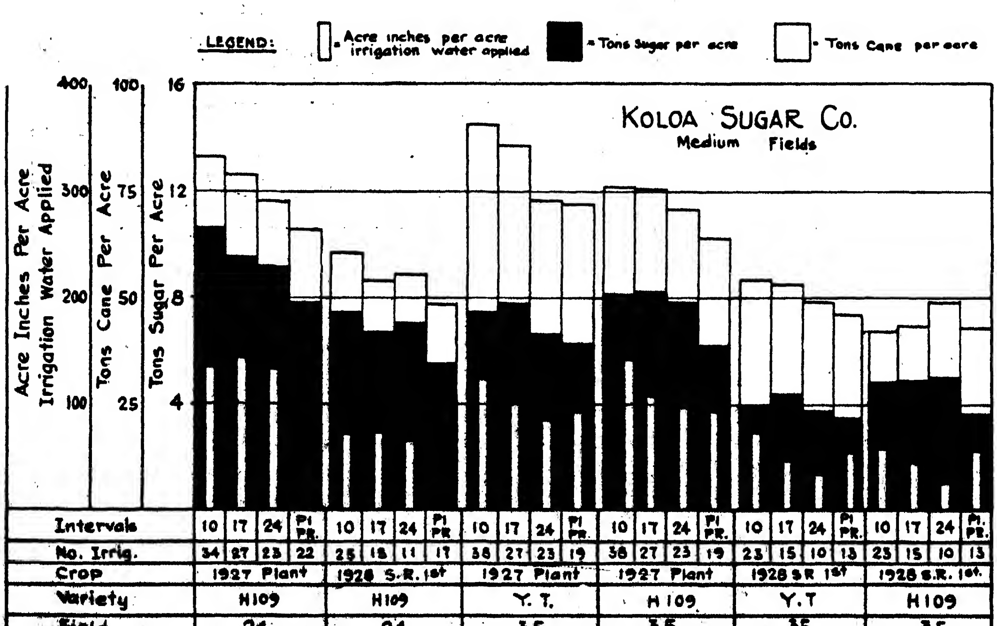


Fig. 2

The beneficial effect of frequent irrigation applications on the yield of cane and sugar seems indicated by the results from Field 24, 1927 and 1928 crops. No significant differences in cane or sugar yields between the maximum and normal treatments is indicated by the results of the experiment in Field 35, planted to H 109 and to Yellow Tip varieties for the crops of 1927 and 1928, although each of the three treatments resulted in a higher yield than that of the plantation practice. It seems apparent that, although soil and climatic conditions would seem to be more conducive to longer intervals between irrigation than those maintained in the "dry" fields, increased yields resulted from increasing the frequency of irrigations over the usual practice. No varietal differences between H 109 and Yellow Tip on the desirable interval between irrigations is apparent from the data. It may follow that the soil type rather than the variety of cane is the governing influence on the amount and frequency of irrigation applications under normal conditions of climate and growth.

CASE III—KOLOA SUGAR COMPANY—"WET" FIELDS

Experiments in the series reported in Fig. 3 are, with the exception of Field 7, which is classed as a "medium" soil, from fields of heavy soil with high moisture-holding characteristics in the poorly drained Mahaulepu district of the plantation.

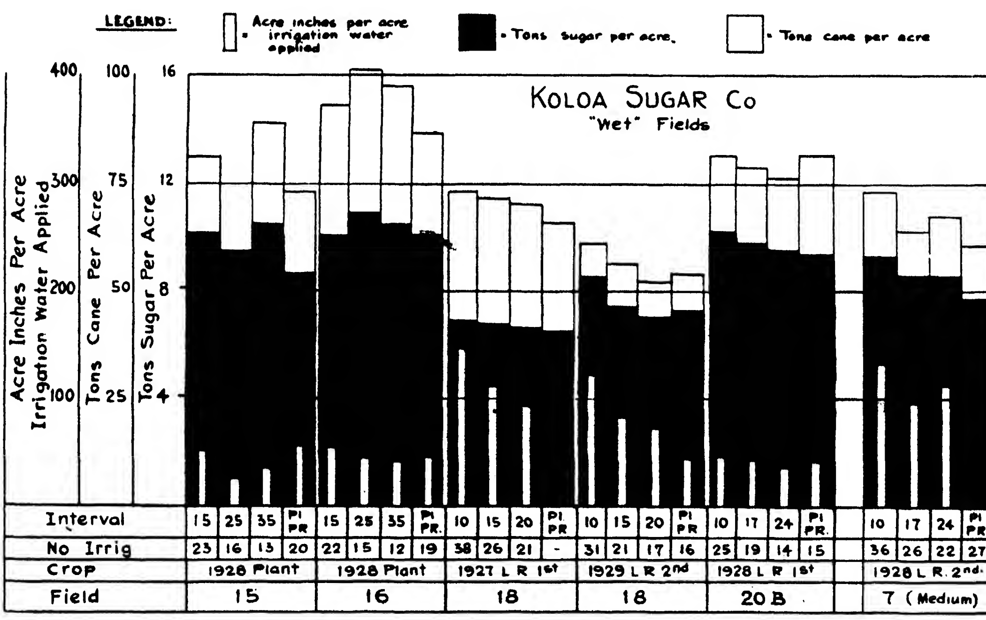


Fig. 3

The results from Field 15 and Field 16 of the 1928 crop appear to point to longer intervals between irrigations for soil of this nature. In the former case, an interval of 35 days gave the highest yield, while in Field 16 the 25-day interval led. Although the plots under the plantation practice received more irrigations than any other treatment except the maximum, yields of both cane and sugar were depressed. The possibility of over-irrigating heavy soils with poor drainage is indicated.

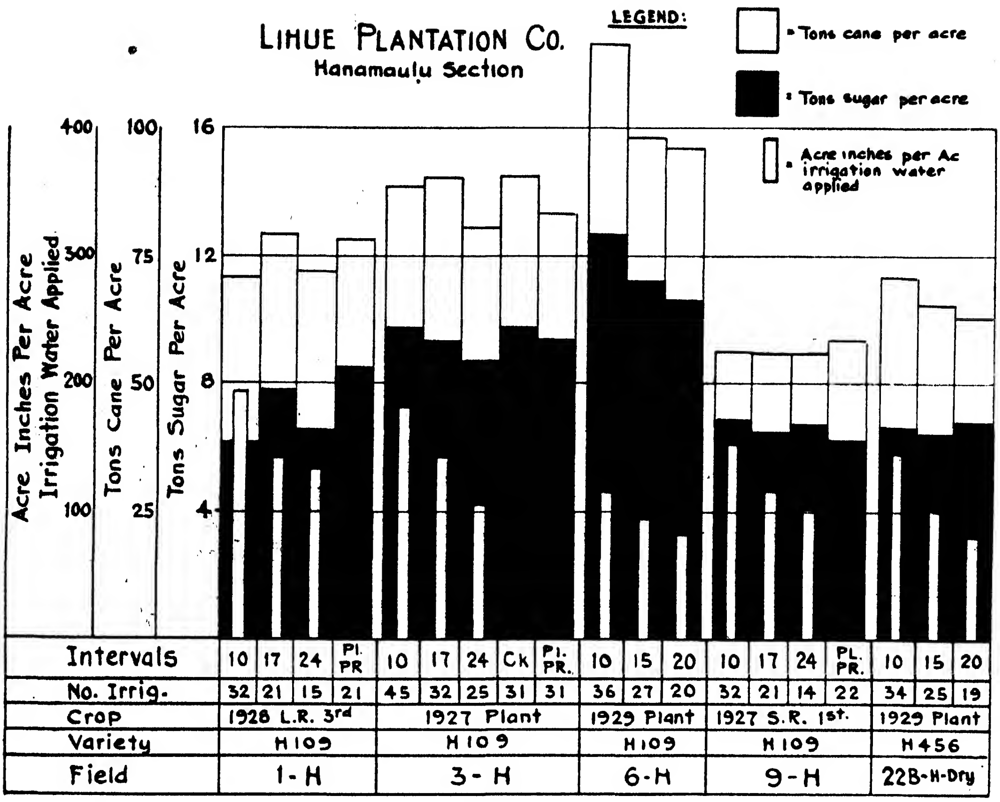

LIHUE PLANTATION CO.
Hanamaulu Section
LEGEND:
= Tons cane per acre
= Tons sugar per acre
= Acre inches per Ac irrigation water applied
Acre Inches Per Acre Irrigation Water Applied
Tons Cane Per Acre
Tons Sugar Per Acre
400 300 200 100
100 75 50 25
16 12 8 4
Intervals | 10 | 17 | 24 | Pl. PR | 10 | 17 | 24 | Ck | Pl. PR. | 10 | 15 | 20 | 10 | 17 | 24 | PL. PR. | 10 | 15 | 20
No. Irrig. | 32 | 21 | 15 | 21 | 45 | 32 | 25 | 31 | 31 | 36 | 27 | 20 | 32 | 21 | 14 | 22 | 34 | 25 | 19
Crop | 1928 L.R. 3rd | 1927 Plant | 1929 Plant | 1927 S.R. 1st. | 1929 Plant
Variety | H109 | H109 | H109 | H109 | H456
Field | 1-H | 3-H | 6-H | 9-H | 22B-H-Dry

Fig. 4

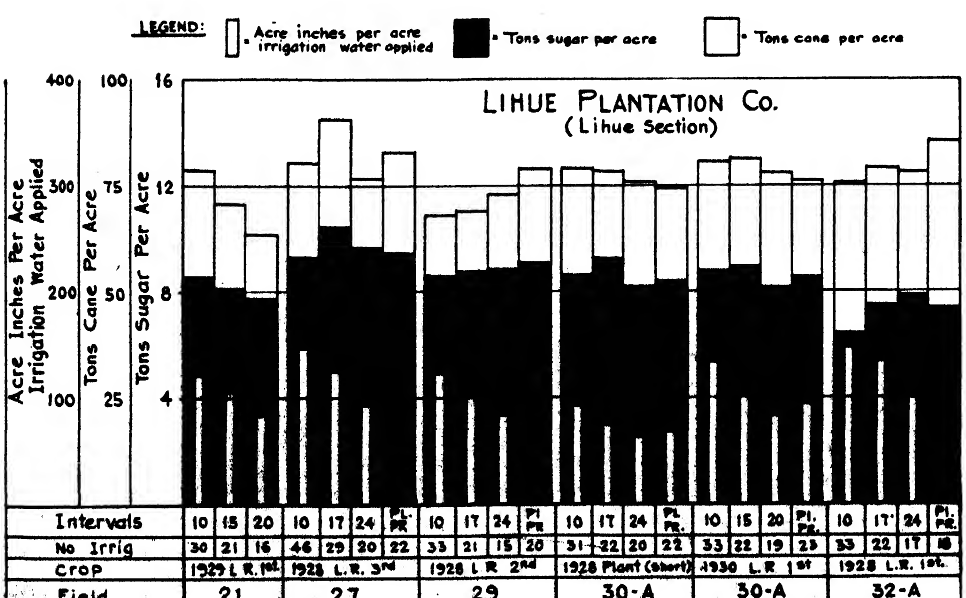

LEGEND:
= Acre inches per acre irrigation water applied
= Tons sugar per acre
= Tons cane per acre
LIHUE PLANTATION CO.
(Lihue Section)
Acre Inches Per Acre Irrigation Water Applied
Tons Cane Per Acre
Tons Sugar Per Acre
400 300 200 100
100 75 50 25
16 12 8 4
Intervals | 10 | 15 | 20 | 10 | 17 | 24 | Pl. PR | 10 | 17 | 24 | Pl. PR | 10 | 17 | 24 | Pl. PR. | 10 | 15 | 20 | Pl. PR. | 10 | 17 | 24 | Pl. PR.
No Irrig | 30 | 21 | 16 | 46 | 29 | 20 | 22 | 33 | 21 | 15 | 20 | 31 | 22 | 20 | 22 | 33 | 22 | 19 | 23 | 33 | 22 | 17 | 18
Crop | 1929 L.R. 1st | 1928 L.R. 3rd | 1928 L.R. 2nd | 1928 Plant (short) | 1930 L.R. 1st | 1928 L.R. 1st.
Field | 21 | 27 | 29 | 30-A | 30-A | 32-A

Fig. 5

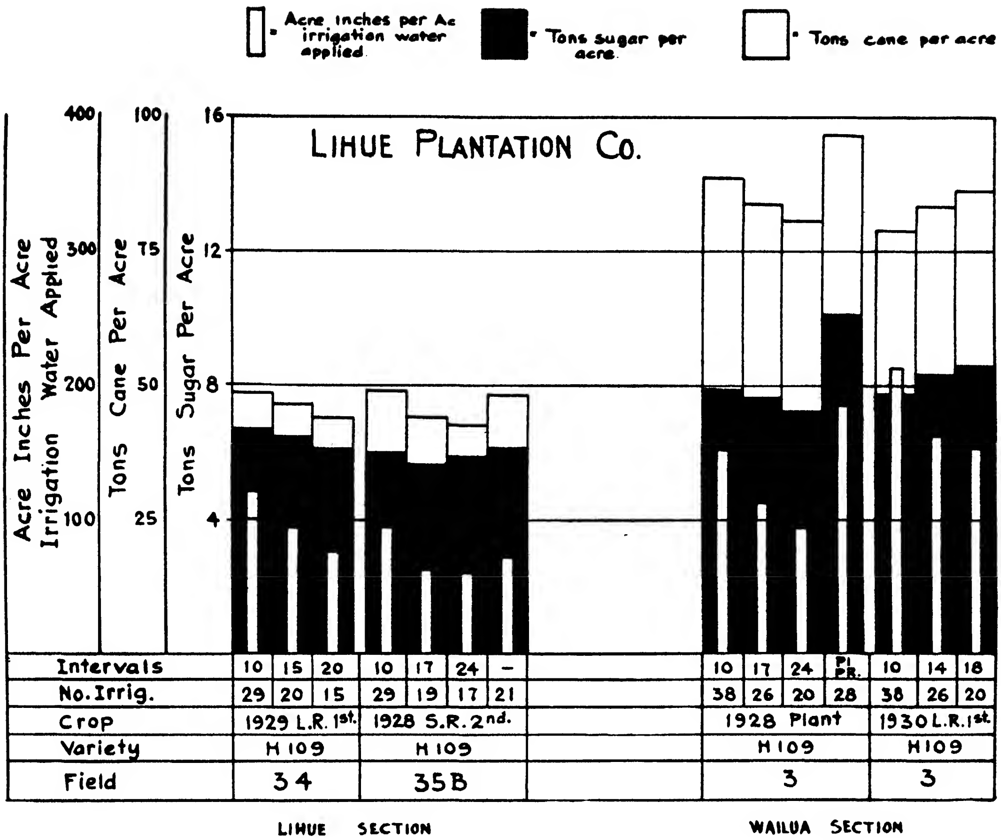


Fig. 6

Although the differences are not as marked as on the dry or medium soils, the remaining experiments of this series seem to show the trend noted previously of a proportional relationship between frequency of irrigation applications and resulting yield. The maximum treatment of 10-day intervals between irrigations resulted in the highest yield of cane and sugar in all cases.

CASE IV—LIHUE PLANTATION COMPANY—HANAMAULU SECTION

The interval tests conducted by Lihue Plantation Company do not, in general, lend themselves to the casual inspection and more apparent interpretation which mark the experiments of the Koloa Sugar Company. Several complicating factors appear to add difficulty to the operation of plantation tests such as those reported here. The plantation possesses diverse and variable soil types which make experimentation in large plots with few replications hazardous. "Blank" tests in which a series of level ditches under uniform treatment of fertilization and irrigation were harvested as individual plots showed great deviations in yield, and indicated marked soil diversity. Many of the experimental fields were ravaged by eye spot and other pathological disturbances. Moreover, it is possibly significant to note that the only experiments which demonstrated clear-cut differences in yields between treatments were those operated independently without comparison with previous practice.

With the exceptions of Field 6-H and Field 22-B-H, which indicate increased yields with more frequent applications of water, no opinion on the most suitable policy of irrigation can be gained from the results of these experiments.

Case V—Lihue Plantation Company—Lihue Section

The majority of the experiments in this series of interval tests likewise fail to demonstrate results which would warrant serious consideration of a change in the plantation irrigation policy.

The results from the experiment in Field 21, with differences of 0.5 ton of sugar between each treatment, are rather clear-cut indications of higher yields from more frequent intervals between irrigations. The 17-day interval in Field 27 established an increase of nearly one ton of sugar over its nearest competitor. The results of the remaining experiments of the series are inconsistent or inconclusive. In nearly every case, the yield from plots under plantation practice was equal to or better than that of other treatments in the series, which might lead one to believe that the usual practice was close to the optimum under the conditions of the experiment.

Case VI—Lihue Plantation Company—Lihue and Wailua Sections

Three of the four experiments in this series point to greater yields from increased frequency of irrigation applications. The proportional trend of yield and interval is apparent in all experiments save that of Field 3 in the 1930 crop. In this case it should be noted that the difference between intervals has been reduced to four days. In general, it appears difficult to determine appreciable differences in results when the interval treatments are spaced too closely together. Differences in interval treatments of about 7 days seem the least which may be expected to reveal definite differences in the results. The minimum interval, 18 days, in Field 3 of the 1930 crop is equivalent to the normal treatment to the same field for the preceding crop.

The usual ability of the plantation practice to equal or better the yields under any of the other treatments is maintained in the experiments of this series.

Case VII—Pioneer Mill Company

The experimental fields reported in Fig. 7 represent a considerable range of soil types and climatic conditions. Field 31 is a red loam soil in the Honokawai Section at 400 feet elevation. The climate is cooler and the rainfall greater than that in the central portion of the plantation. Field MC-9 is an extremely rocky field in the Launipoko Section at an elevation of 250 feet. Field O-10 has a sandy soil, heavily infested with nutgrass, near sea level in the Lahaina Section. The climate is hot and the rainfall relatively slight.

The results of the experiment in Field 31 plainly indicate that increased yields may be expected from more frequent irrigations. This experiment is considered by the plantation staff to be an outstanding example of the value of interval tests on the plantation. Prior to the completion of the experiment it had been felt that,

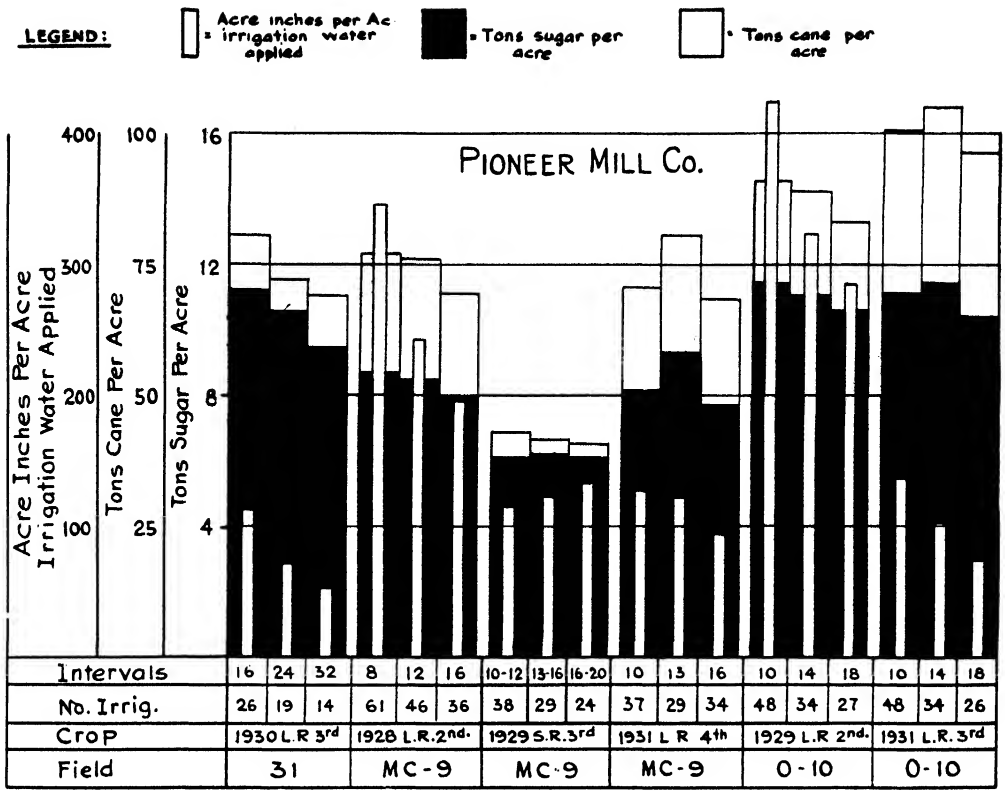


Fig. 7

due to the higher elevation and cooler climate, intervals between irrigations in the Honokawai Section could be extended far beyond those of fields in the warmer portion of the plantation. The results of the experiment indicated the necessity of a change in policy toward more frequent irrigations.

C. E. S. Burns, manager of Pioneer Mill Company, states: "We at Pioneer feel that the interval tests which we have conducted are of considerable value. Formerly we thought 30-day water was fast enough in the Honokawai Section, and during the dry spells we were lucky if it did not go twice that long. The interval tests in Field 31 show plainly the results of shorter irrigation intervals. We now try to keep the normal interval around 15 days. On the warmer sections of the plantation, most of Wahikuli and Lahaina, it has always been the practice to get around with the water every 10 to 12 days. Tests show this to be about right."

Results from the other experiments in this series are less conclusive due, perhaps, to the slight differences between intervals in the various treatments. Field MC-9 in the 1928 crop showed little difference in results between the maximum and normal intervals, but a considerable decrease resulted in plots under the minimum treatment. A flexible schedule with but slight variation between treatments was attempted in the 1929 crop, but little significance in the results was established. The experiment continued in the 1931 crop with interval differences of three days between treatments, and showed the highest yield from the 13-day interval. The

results of the experiment after three successive crops show a decided trend toward frequent irrigations at intervals of 10 to 13 days.

The sandy O-10 field for the 1929 crop indicated slightly higher yields under the maximum frequency of irrigation, but at the price of a tremendous consumption of water. In 1931, the same experiment showed a slight gain from the 14-day treatment over the other plots. Again, the little variation between intervals to the different plots tended to mask decisive differences between treatments or between the results of successive crops.

One of the practical advantages of the interval test is illustrated in the results of the experiments in Fields MC-9 and O-10. For the first crop in which the test was conducted, tremendous amounts of irrigation water, which for one treatment totalled 423.60 acre-inches per acre for the crop, were applied. In the succeeding crop, the management was able to reduce these applications from one-half to two-thirds of the previous total.

Case VIII—Pioneer Mill Company

The experiments of this series are from three fields repeated for two successive crops. The results indicate the advisability of repeating interval tests for two or more crops if confidence is to be placed in the conclusions drawn from the experiment. Field I-5 is a rocky, red-loam soil at an elevation of 75 feet. Field C-6 is a red-loam soil at 250 feet elevation in the Puukolii Section of the plantation. Field B-4, also in the Puukolii Section, is a red-loam at an elevation of 500 feet.

The figures reported in Fig. 8 show that in Field I-5, 1928 crop, the results were indecisive with a gain of less than 0.2 of a ton of sugar in favor of the

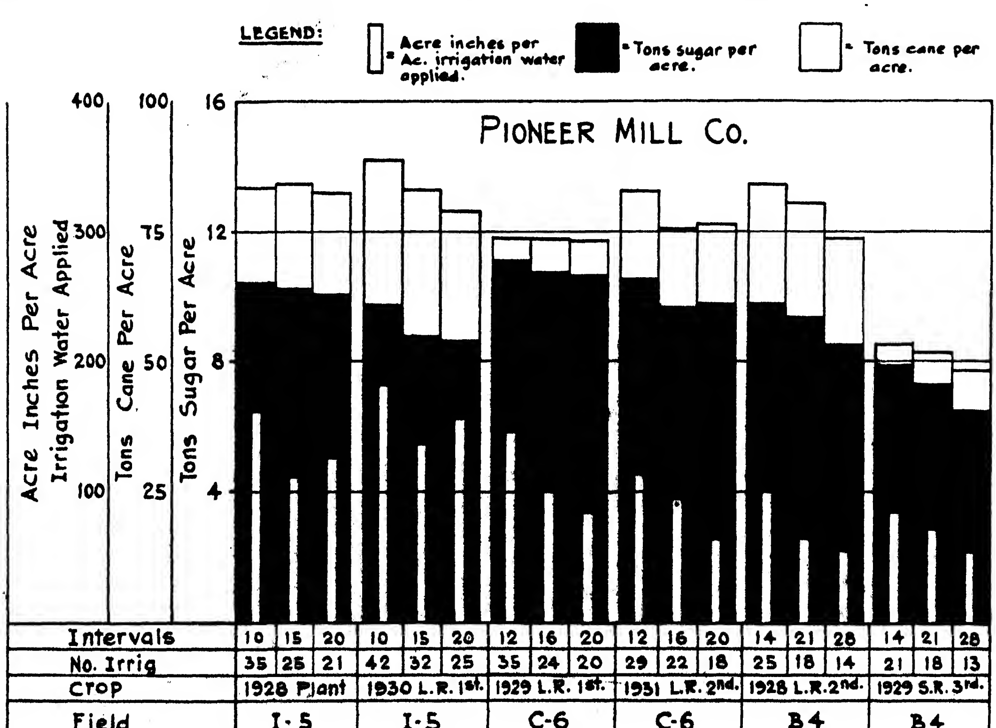


Fig. 8

maximum interval. In the 1930 crop of the same experiment, however, a clear-cut verdict in favor of frequent applications of irrigation water seems apparent.

Experiment C-6 of the 1929 crop likewise failed to demonstrate significant differences between treatments although the trend appears to favor the closer interval between applications. On repetition of the experiment in the 1931 crop, the gain in yield of the plots under the maximum interval over the normal and minimum treatments appears conclusive, although no significant differences appear between the last two treatments.

The test in Field B-4 demonstrated proportional decreases in yield with longer intervals between irrigations for both the 1928 and 1929 crops. In general, the plantation seems justified in concluding that increased yields can be gained, especially in the Puukolii Section, from increased frequency of irrigation applications.

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Response of Cane Plants to Soil Sterilization

By J. N. P. Webster

During 1931, some studies were made on the growth of cane seedlings in flats containing various mixtures of soil, with compost, mudpress, black sand, bagasse and beet compost, in sterilized and unsterilized condition. It was noted that in practically every case seedlings growing in mixtures which had been sterilized made better growth than those planted in unsterilized mixtures. Thus it would seem that the sterilization of the soil resulted in some beneficial effect.

To determine if this influence would be shown in ordinary Makiki soil planted to different varieties of cane it was decided to install a small experiment using large tubs.

Experiment No. 1

A sufficient amount of soil to a depth of about eight inches was removed from Field 6 of the Makiki plots and thoroughly composited. One part was then immediately placed in tubs in an unsterilized condition. A second part was placed in bags and sterilized with steam in the same manner as soil used in seedling work, and then put into the tubs. The third part was sterilized by formaldehyde. A large tarpaulin was spread on a floor and as the soil was added in thin layers, making a pile, a solution of formaldehyde was sprinkled over each layer. Ten gallons of a solution of 40 per cent formaldehyde made up in the proportion of one gallon to 50 gallons of water was used. The sprinkled pile was then covered with the remaining area of the tarpaulin and allowed to remain for two days. At the end of this time the covering was removed, the pile spread out over the tarpaulin in a thin layer and mixed once every day for a week before the soil was placed in the tubs.

A total of 27 galvanized tubs each holding approximately 140 pounds of soil were used. One set of each treatment was planted with four seed pieces of each of the following varieties:

H 109
Yellow Caledonia
D 1135
Striped Tip
P. O. J. 36
P. O. J. 2878
Natal Uba
Badila
Lahaina

Immediately after planting, the tubs were thoroughly irrigated and covered with a double thickness of wax-paper, which was allowed to remain for three days. Germination was excellent in all tubs.

Fig. 1

Fig. 2


Mahiki Soil
Steam
Sterilized

Fig. 3


Mahihi Soil
Steam
Sterilized
Mahihi Soil
Formaldehyde

Fig. 4

The tubs were planted on March 18, 1931, and beyond being given sufficient irrigation no fertilizer treatment of any kind was used. The plants were harvested from May 26 to June 8 or when they were approximately 75 days old.

In Table I are given the dry weights of the tops and roots of the various varieties.

TABLE I

Showing Dry Weights, in Grams, of Tops and Roots

	Badila		Yellow Caledonia		P.O.J. 2878	
	Tops	Roots	Tops	Roots	Tops	Roots
Unsterilized	157.0	78.5—	135.1	143.9+	132.3	75.5—
Steam sterilized	361.9	369.2+	288.4	514.9+	259.0	271.7+
Formaldehyde sterilized	426.9	259.3—	358.3	275.7—	213.0	132.7—
	D 1135		Striped Tip		P.O.J. 36	
	Tops	Roots	Tops	Roots	Tops	Roots
Unsterilized	106.4	110.7+	91.9	110.8+	83.8	74.9—
Steam sterilized	242.3	247.5+	225.1	163.8—	270.5	320.2+
Formaldehyde sterilized	315.7	199.5—	196.0	244.2+	297.5	333.6+
	H 109		Natal Uba		Lahaina	
	Tops	Roots	Tops	Roots	Tops	Roots
Unsterilized	83.0	45.3—	78.2	101.1+	69.4	45.7—
Steam sterilized	197.0	135.7—	235.9	285.8+	99.8	88.0—
Formaldehyde sterilized	128.4	122.6—	76.2	121.7+	79.7	59.0—

From a study of the above table it can be seen that in every case the sterilized soils showed a greater top and root growth than any unsterilized soil. The top growth of Natal Uba on the formaldehyde sterilized soil shows a slightly depressed weight when compared with that of the unsterilized soil, and the root weight is in favor of the formaldehyde sterilized soil. It is difficult to assign any reason for the lack of top growth.

Figs. 1, 2, 3 and 4 show the growth made by some of the varieties under the different soil treatments.

Through the kindness of C. W. Carpenter, of the pathology department, and R. H. Van Zwaluwenburg, of the entomology department, a study of the root systems was made. The discussion of their findings is given below:

Herewith is submitted a report on an examination of the roots of 27 samples of cane from an experiment conducted by J. N. P. Webster. These 27 samples consisted of 9 varieties in three series as follows.

A Check Makiki soil
B Steam sterilized Makiki soil
C Formaldehyde treated Makiki soil

The varieties of cane were as follows:

D 1135	Lahaina
P. O. J. 2878	Badila
Yellow Caledonia	Natal Uba
P. O. J. 36	Striped Tip
H 109	

The top growth of the canes in the treated soils was in general so superior to that of the plants in the natural Makiki soil that it seemed worth while to know whether or not the observed improvement was due to repression of parasitic organisms, and with that in mind the roots were examined.

The root systems of all plants were carefully washed. The following general observations were made:

1. The root growth of the plants in the steam sterilized soil was in most cases superior to, and in all cases at least equal to, that obtained in formaldehyde treated soil.

2. The root systems in the treated soils were in all cases far superior to those in the natural soil. By superior is meant of greater bulk and with a very conspicuous increase of fine rootlets, particularly in the upper 6 inches of soil. (A single exception was the Natal Uba in soil treated with formaldehyde; here depression resulted.)

3. The roots in the treated soils were conspicuously lighter in color than those in the checks.

4. The roots of all three series showed conspicuous injury due to contact with the container.

5. *Heterodera radicicola* and *Tylenchus similis* were identified in all pots of the check series. In every case, however, damage by these nematodes was so slight that it was impossible for us to believe that the marked reduction in root and top growth shown throughout the check series was due to these factors. No evidence of rootlets having been destroyed by nematodes was seen in the check series. In only two cases of treated pots, one steam sterilized, the other formaldehyde treated, were traces of Heterodera found. No Tylenchus was found in roots of treated pots.

6. No evidence of Pythium root rot was observed in the series in treated soils. In the natural soil an occasional softened root was found, but in no case was the fungus Pythium definitely observed. Such roots as were softened appeared to have succumbed as a result of stagnation in the water in depressions at the bottom of the pots.

The striking difference between the roots of treated and check pots was the comparative lack of fine rootlets in the latter. There was no evidence that this lack of fine roots was due to the destruction by parasitic organisms of rootlets already formed. On the contrary such rootlets apparently had never been developed in corresponding abundance in the check plants.

It is our presumption therefore that the essential factors controlling the abundant production of secondary rootlets are physical and nutritional in nature. Where ample nutrients in an improved physical environment were available, a close mat of fine roots developed.

We suggest that if this project is to be followed, a series of soils be included wherein a superabundance of nutrients is present in both sterilized and unsterilized units, to eliminate the possible lack of nutrient factors. Fine screened soil might be used to make the physical condition of steamed and check soil more nearly comparable. Inoculation of a series of steamed soils by the introduction of small amounts of natural soil might throw additional light on the biological-nutritional phases of the problem.

Experiment No. 2

The above showing of the response of the plants to soil sterilization led to the idea of attempting to duplicate the response by the use of high phosphate fertilization, a complete fertilizer mixture and by the use of chloropicrin.

Accordingly, sufficient soil was obtained from Field 3 at Makiki, which was screened and then thoroughly composited. One-half was steam sterilized under pressure for two and one-half hours while the other half was used unsterilized.

It was decided to use the variety D 1135 in this experiment, and to use two tubs for each treatment. The tubs were the same as those used in the previous experiment.*

The following were the treatments used in the sterilized and unsterilized soils:

1. Sterilized soil control.
2. " " + 1000 lbs. P_2O_5 per acre.
3. " " + 1500 lbs. P_2O_5 per acre.
4. " " + 100 lbs. N, 500 lbs. P_2O_5, 500 lbs. K_2O per acre.
5. " " + chloropicrin, 75 lbs. per acre.
6. " " + pythium.
7. " " + 2 lbs. unsterilized soil*.
8. Unsterilized soil control.
9. " " + 1000 lbs. P_2O_5 per acre.
10. " " + 1500 lbs. P_2O_5 per acre.
11. " " + 100 lbs. N, 500 lbs. P_2O_5, 500 lbs. K_2O per acre.
12. " " + chloropicrin, 75 lbs. per acre.
13. " " + pythium.

The fertilizers were thoroughly incorporated in the soil before it was placed in the tubs.

In the case of the chloropicrin, soil to a depth of about three inches was first placed in the tubs and then the required amount of chloropicrin was poured on this layer and quickly covered with the amount of soil required to fill the tubs. The tubs were tightly covered with paper and allowed to remain for 4 days.

On July 21, 1931, seed of D 1135 was obtained from Waipio, given the hot water treatment and three seedpieces were planted to every tub. The tubs were then irrigated, covered with paper and left for 3 days before the paper was removed. At this time pure cultures of pythium were added to the designated tubs of the series by thoroughly mixing the cultures in the surface one inch of soil.

Germination and growth of the plants was satisfactory and it was noted that the plants in the sterilized soil series made much better growth than the plants in the unsterilized soil series.

On October 30, the plants in all tubs were photographed, harvested, and the root masses separated from the soil.

Figs. 5, 7, 8, 9 and 10 show the top growth of some of the plants of this series, while Figs. 6 and 11 show the root masses of two groups. In the latter, the mass of very fine fibrous roots can be seen. These were characteristic of the sterilized series in every case.

* This unsterilized soil was obtained from several very poor areas in the upper Ewa corner of Field 8, Makiki.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

The following table shows the dry weights of the tops and roots of the series.

TABLE II

Treatments	Sterilized Soil Tops	Sterilized Soil Roots	Unsterilized Soil Tops	Unsterilized Soil Roots
Check	360.1	140.2	....	....
Unsterilized soil added (2 lbs.)	385.6	134.2	115.6	69.9
1000 lbs. P_2O_5	326.3	130.5	89.6	60.8
1500 lbs. P_2O_5	291.2	132.9	95.8	58.1
100 lbs. N, 500 lbs. P_2O_5, 500 lbs. K_2O	419.6	111.5	160.5	89.8
Pythium	405.1	111.0	86.4	49.1
Chloropicrin 75 lbs. per acre	380.1	145.0	229.6	102.3

A first glance at the above table shows the remarkable gain of the top and root weight of the sterilized soil series over the unsterilized series.

The greater weight of tops and roots of the sterilized soils is in accord with that found in Experiment 1.

The response to chloropicrin in the unsterilized soil is considerable and is probably due to its sterilizing effect upon the soil.

A study of the root systems in the sterilized and unsterilized soils was made by Mr. Van Zwaluwenburg and he comments briefly as follows:

October 30, 1931. Examined today material from two tubs of J. N. P. Webster's experiment, as follows: (1) unsterilized Makiki soil, (2) steam sterilized Makiki soil. Both were supporting plant D 1135 cane, 101 days old.

Examination of roots:

Sterilized soil—No nematodes found within the roots.

Unsterilized soil—Colonies of *Tylenchus similis* were found within the roots. Lesions were few on the entire root mass, and not conspicuous.

Examination of soil:

Sterilized—Hoplolaimus sp. (nematode).
One species of amoeboid protozoan.

Unsterilized—Dorylaimus sp. (nematode).
At least 3 species of protozoans:
Paramoecium
Another ciliated protozoan
Amoeboid protozoan

In the *Monthly Letter* for October, 1931, the following resumé was made of the work at Rothamsted in regard to the study of plant growth in sterilized and unsterilized soils:

It has been pointed out upon different occasions that roots grown in sterilized soils are more finely divided and the mass is much greater than those grown in unsterilized soils. In an experiment recently completed by J. N. P. Webster, wherein D 1135 was grown in sterilized vs. unsterilized soils, the various root systems were studied by D. M. Weller in order to determine if the fine roots, that are present in the sterilized soil, actually start in the unsterilized soil and if the absence of these fine roots in the latter are due to parasitic organisms.

A histological study of these roots is in progress and Mr. Weller comments as follows:

"So far certain apparent differences are seen. Immediately outside of the endodermis of the roots in unsterilized soil appears a layer of cells of very much thickened cell walls

and dead protoplasts. This same layer of cells in plants grown in sterilized soil appears to be much less lignified and has fewer dead protoplasts, as though the life of these cells had been prolonged. No doubt this would influence absorption."

As a matter of general interest it seems desirable to present a summary of the research work conducted on this subject by investigators in England. Mr. Carpenter has reviewed some of the literature and offers the following comments:

"This subject was exhaustively studied at Rothamsted Experimental Station under the leadership of Dr. E. J. Russell, during the period 1907-1924. Valuable contributions have been made by Hiltner and Stormer, and by Greig Smith. No attempt has been made to cite or list the abundant correlative literature of Germany, France and America.

"A few of the more significant statements made in the literature, in summarizing extensive research projects, are quoted, as follows:

E. J. Russell and H. B. Hutchinson: The Effect of Partial Sterilization of Soil on the Production of Plant Food, *Journal of Agricultural Science,* Vol. III, 1909, p. 120:

1. The increased productiveness of partially sterilized soils is due to an increase in the amount of ammonia present.

2. The excess of ammonia is the result of increased decomposition of soil substance by bacteria.

3. Hiltner and Stormer's discovery that the bacteria increase rapidly after partial sterilization, and finally become much more numerous than in the original, untreated soil, is confirmed. The increase in number proceeds *pari passu* with the increase in ammonia.

6. Chemical hypothesis having been found unsatisfactory, the factor is shown to be biological. Large organisms (protozoa) were found in untreated, but not in the partially sterilized soils, at least two of which are known to destroy bacteria.

Francis Darbishire and Edward J. Russell: Oxidation in Soils and Its Relation to Productiveness, *Ibid.,* Vol. II, 1907, pp. 325-326:

1. Partial sterilization of soil either by heating to 100° C. or by treatment with volatile antiseptics, which are subsequently removed, leads to a marked increase in the amount of oxygen absorbed by the micro-organisms of the soil.

2. The yield of non-leguminous crops is distinctly larger on partially sterilized than on unsterilized soil. Leguminous crops, however, show no increase.

3. Analysis shows that partial sterilization causes an increase in the amount of nitrogen, phosphoric acid and potash taken up by the crop, and in the percentage of nitrogen and phosphoric acid in the dry matter. . . .

4. The increased availability of the plant food appears to be connected with the modification of the bacteria flora brought about by partial sterilization. When the soil is heated, however, chemical decomposition also takes place."

The statement is made elsewhere by Dr. Russell that no increase in growth follows partial sterilization of soils amply supplied with ammonia and nitrates.

In the following article by E. J. Russell it is pointed out that in sterilization of the soil the protozoan life is destroyed. Certain protozoa are known to live entirely upon bacteria and in this way the numbers of bacteria are kept in check. Bacteria, because they change into a spore form, are much more resistant to heat than protozoa. Therefore, after sterilization there is an increase in the bacterial flora which is probably responsible for the greater plant growth.

It is interesting to note, in this respect, that in his examination of samples of soil from the sterilized and unsterilized material Mr. Van Zwaluwenburg found only one protozoan species in the sterilized soil whereas in the unsterilized soil he found three forms.

ORGANISMS NOT DIRECTLY AFFECTING PLANT GROWTH BUT ACTING ON THOSE THAT DO.—Investigation on the Partial Sterilization of the Soil.—(From *Soil Conditions and Plant Growth*—By Edward J. Russell, pp. 169-177—Third Edition.)

The earliest observations that soil is altered by an apparently inert antiseptic arose out of attempts to kill insect pests in the soil by means of carbon disulphide. This substance, which for fifty years has been known as an insecticide, was used in 1877 by Oberlin, an Alsatian vine-grower, to kill phylloxera, and by Girard in 1887 to clear a piece of sugar-beet ground badly infested with nematodes. In both cases the subsequent crops showed that the productiveness of the soil had been increased by the treatment.

The first piece of scientific work came from A. Koch, in 1899, who, working with varying quantities of carbon disulphide, concluded that it stimulates the plant root to increased growth. Four years later Hiltner and Stormer showed that the bacterial flora of the soil undergoes a change. The immediate effect of the antiseptic was to decrease by about 75 per cent the number of organisms capable of developing on gelatin plates; then as soon as the antiseptic had evaporated, the numbers rose far higher than before, and there was also some change in the type of flora. It was argued that the increased numbers of bacteria must result in an increased food supply for the plant, and it was claimed that the new type of flora was actually better than the old, in that denitrifying organisms were killed, nitrogen-fixing organisms increased, and nitrification only suspended during a period when nitrates were not wanted and might undergo loss by drainage. In a later publication Hiltner shows that other volatile or easily decomposable antiseptics produce the same effect. The important part of this work is unquestionably the discovery that the organisms in the treated soils ultimately outnumber those in the original soil. The hypothesis that the new type of flora is actually more efficient than the old rests on less trustworthy evidence, and has indeed been modified in some of its details by Hiltner himself.

The effect of heat on the productiveness of the soil was first noticed by the early bacteriologists. It had been assumed that heat simply sterilized the soil and produced no other change, until Frank in 1888 showed that it increased the soluble mineral and organic matter and also the productiveness. Later work by Pfeiffer and Franke and by Krüger and Schneidewind showed that plants actually take more food from a heated than from an unheated soil. Heat undoubtedly causes decomposition of some of the soil constituents quite apart from its effect on the soil flora; it also produces physical effects.

The writer's investigation on this subject began in the first instance as the result of an accident. In virtue of its large population of micro-organisms soil absorbs a considerable quantity of oxygen, and evolves a corresponding amount of carbon dioxide. An experiment had been arranged to demonstrate the well-known fact that soil heated to 130° C., and therefore completely devoid of micro-organisms, lost much of its power of absorbing oxygen. By an accident the autoclave was not available; the soil was therefore only heated in the steam oven, and it gave the remarkable result that its power of absorbing oxygen instead of falling, as was expected, considerably increased. Now the steam did not kill all the organisms, but spared those capable of forming spores; i.e., sterilization was only partial. Partial sterilization by means of volatile antiseptics gave the same result. The conclusion was drawn that partial sterilization increased the bacterial activity, and consequently the amount of decomposition. The increased quantity of plant food thus formed is shown by the amounts taken up by the plant.

Further investigations by Russell and Hutchinson led to the following conclusions:

(1) Partial sterilization of soil, i.e., heating to a temperature of 60° C. or more, or treatment for a short time with vapors of antiseptics such as toluene, causes first a fall then a rise in bacterial numbers. The rise sets in soon after the antiseptic has been removed and the soil conditions are once more favorable for bacterial development; it goes on till the numbers considerably exceed those present in the original soil.

(2) Simultaneously there is a marked increase in the rate of accumulation of ammonia. This sets in as soon as the bacterial numbers begin to rise, and the connection between the

two quantities is normally so close as to indicate a causal relationship; the increased ammonia production is, therefore, attributed to the increased numbers of bacteria. There is no disappearance of nitrate; the ammonia is formed from organic nitrogen compounds.

(3) The increase in bacterial numbers is the result of improvement in the soil as a medium for bacterial growth and not an improvement in the bacterial flora. Indeed the new flora per se is less able to attain high numbers than the old. This is shown by the fact that the old flora when reintroduced into partially sterilized soil attains higher numbers and effects more decomposition than the new flora. Partially sterilized soil plus 0.5 per cent of untreated soil soon contains higher bacterial numbers per gram and accumulates ammonia at a faster rate than partially sterilized soil alone.

(4) The improvement in the soil brought about by partial sterilization is permanent, the high bacterial numbers being kept up even for 200 days or more. The improvement, therefore, did not consist in the removal of the products of bacterial activity, because there is much more activity in partially sterilized soil than in untreated soil. Further evidence is afforded by the fact that a second treatment of the soil some months after the first produces little or no effect.

It is evident from (3) and (4) that the factor limiting bacterial numbers in ordinary soils is not bacterial, nor is it any product of bacterial activity, nor does it arise spontaneously in soils.

(5) But if some of the untreated soil is introduced into partially sterilized soil, the bacterial numbers, after the initial rise (see (3)), begin to fall. The effect is rather variable, but is usually most marked in moist soils that have been well supplied with organic manures, e.g., in dunged soils, greenhouse soils, sewage farm soils, etc. Thus the limiting factor can be reintroduced from untreated soils.

(6) Evidence of the action of the limiting factor in untreated soils is obtained by studying the effect of temperature on bacterial numbers. Untreated soils were maintained at 10°, 20°, 30°, C., etc., in a well-moistened, aerated condition, and periodical counts were made of the numbers of bacteria per gram. Rise in temperature rarely caused any increase in bacterial numbers; sometimes it had no action, often it caused a fall. But after the soil was partially sterilized the bacterial numbers showed the normal increase with increasing temperatures.

EFFECT OF TEMPERATURE OF STORAGE ON BACTERIAL NUMBERS IN SOILS, MILLIONS PER GRAM

Temperature of Storage ° C.	Untreated Soil At start	After 13 days	After 25 days	After 70 days	Soil Treated with Toluene At start	After 13 days	After 25 days	After 70 days
5°-12°	65	63	41	32	8.5	73	101	137
20°	65	41	22	23	8.5	187	128	182
30°	65	27	50	16	8.5	197	145	51
40°	65	14	9	33	8.5	148	52	100

Similar results were obtained by varying the amount of moisture but keeping the temperature constant (20° C.). The bacterial numbers in untreated soil behaved erratically and tended rather to fall than to rise when the conditions were made more favorable to trophic life; on the other hand, in partially sterilized soil, the bacterial numbers steadily increased with increasing moisture content. Again, when untreated soils are stored in the laboratory or glass-house under varying conditions of temperature and of moisture content the bacterial numbers fluctuate erratically; when partially sterilized soils are thus stored the fluctuations are regular.

(7) When the curves obtained in (6) are examined it becomes evident that the limiting factor in the untreated soils is not the lack of anything but the presence of something active.

(8) This factor, as already shown, is put out of action by antiseptics and by heating the soil to 60° C., and once out of action it does not reappear. Less drastic methods of treating the soil put it out for a time, but not permanently; e.g., heating to 50°, rapid

drying at 35°, treatment with organic vapors less toxic than toluene (e.g., hexane), incomplete treatment with toluene. In all these cases the rise induced in the bacterial numbers per gram is less in amount than after toluene treatment and is not permanent; the factor sets up again. As a general rule, if the nitrifying organisms are killed the limiting factor is also extinguished; if they are only temporarily suppressed the factor also is only put out for a time.

(9) The properties of the limiting factor are:

(a) It is active and not a lack of something (see (7)).

(b) It is not bacterial (see (3) and (4)).

(c) It is extinguished by heat or poisons, and does not reappear if the treatment has sufficed to kill sensitive and non-spore-forming organisms; it may appear, however, if the treatment has not been sufficient to do this.

(d) It can be reintroduced into soils from which it has been permanently extinguished by the addition of a little untreated soil.

(e) It develops more slowly than bacteria, and for some time may show little or no effect, then it causes a marked reduction in the numbers of bacteria, and its final effect is out of all proportion to the amount introduced.

(f) It is favored by conditions favorable to trophic life in soil, and finally becomes so active that the bacteria become unduly depressed. This is one of the conditions obtaining in glass-house "sick" soils.

It is difficult to see what agent other than a living organism can fulfil these conditions. Search was, therefore, made for larger organisms capable of destroying bacteria, and considerable numbers of protozoa were found. The ciliates and amoebae are killed by partial sterilization. Whenever they are killed the detrimental factor is found to be put out of action, the bacterial numbers rise and maintain a high level. Whenever the detrimental factor is not put out of action the protozoa are not killed. To these rules we have found no exception.

NUMBERS OF BACTERIA AND AMMONIA PRODUCTION IN PARTIALLY STERILIZED SOILS

Soil Treatment	Number of Organisms per Gram of Dry Soil, in Millions, Gelatin Plate Cultures: At beginning	After 7 days	After 21 days	After 68 days	After 142 days	Protozoa Found	Ammonia and Nitrate produced after 68 days
Untreated	11	10	12	11	4	C. A. M.	14
Heated to 40°...	7	9	10	8	3	C. A. M.	15
56°...	2	14	16	38	48	M	60
70°...	2	17	11	24	27	M	38
100°...	0.01	17	22	10	10	...	44

C = ciliates. A = amoebae. M = Monads.

Further, intermediate effects are obtained when a series of organic liquids of varying degrees of toxicity is used in quantities gradually increasing from small ineffective up to completely effective doses. The detrimental factor is not completely suppressed but sets up again after a time, so that the rise in bacterial numbers is not sustained. But the parallelism with ciliates and amoebae is still preserved; they are completely killed when the detrimental factor is completely put out of action; they are not completely killed, but only suppressed to a greater or less degree, when the detrimental factor is only partly put out of action.

Now the parallelism between the properties of the detrimental factor and the protozoa is not proof that the protozoa constitute the limiting factor, but it affords sufficient presumptive evidence to justify further examination. The obvious test of adding cultures of protozoa to partially sterilized soil was made, but no depression in bacterial numbers was obtained, instead there was sometimes a rise. But in view of the history of investigations on malaria and other protozoan diseases no great significance was attached to this early failure.

At this stage the investigation was divided into two parts:

(1) The study of the soil protozoa.

(2) The effects of the limiting factor on the biochemical processes on the soil.

No attempt had ever been made in any of the above experiments to identify the protozoa or even to ascertain whether any particular form existed in the soil in the trophic state or as cysts. The variety of forms was considerable, and it soon became evident that a definite protozoological survey of the soil was required.

This was accordingly put in hand. In order to give the survey as permanent a value as possible the investigations were not confined to the narrow issue whether soil protozoa do or do not interfere with soil bacteria, but they were put on the broader and safer lines of ascertaining whether a trophic protozoan fauna normally occurs in soil, and, if so, how the protozoa live, and what is their relation to other soil inhabitants.

The first experiments were made by Goodey mainly with ciliates and indicated that these protozoa were present only as cysts. Subsequent investigations, however, by Martin and Lewin have established the following conclusions:

(1) A protozoan fauna in a trophic state normally occurs in soils.

(2) The trophic fauna found in the soil differs from that developing when soil is inoculated into hay infusions; the forms which appear to predominate in the soil do not predominate in the hay infusions, and vice versa the forms predominating in the hay infusions do not necessarily figure largely in the soil.

(3) The trophic fauna is most readily demonstrated, and is therefore presumably most numerous, in moist soils well supplied with organic manures, e.g., in dunged soils, greenhouse soils, sewage soils and especially glass-house "sick" soils.

Finally, the latest experiments by Goodey have shown that when this trophic fauna is introduced into partially sterilized soils the bacterial numbers are brought down. The earliest attempts to carry out this experiment failed as already stated, only one successful experiment by Cunningham being on record. It was not till Goodey discovered the conditions for successful inoculation that it could be carried out. Goodey found that mass cultures of protozoa failed when introduced direct from a culture medium into partially sterilized soils, but succeeded when introduced through the medium of some untreated soil. In these circumstances the protozoa lived, and the numbers of bacteria were reduced. The protozoa used in these investigations were amoebae of the limax type, these being the forms common in the soil.

Thus it was proved that these protozoa lead an active life in the soil, and that one result of their activity is to keep down the numbers of bacteria.

The following summary of the work done by Waksman and Starkey at the New Jersey Agricultural Experiment Station in the article entitled "Partial Sterilization of Soil, Microbiological Activities and Soil Fertility," *Soil Science*, Vol. XVI, 1923, pp. 137-156, 247-268, 343-356, is of interest:

From page 355:

1. Partial sterilization of soil brings about a chemical change in the organic matter of the soil, making it more available as a source of energy for micro-organisms. This is indicated by (a) the ammonia formation (even if only a small amount) in the process of sterilizing the soil by heat or disinfectants; (b) by the fact that the curve of CO_2-evolution in partially sterilized soil is similar to that obtained when a small amount of undecomposed organic matter is added to unsterilized soil; (c) by the fact that soils rich in organic matter allow a greater accumulation of ammonia and nitrates, as a result of partial sterilization, than soils poor in organic matter, independent of the flora and fauna; (d) partially sterilized soil with a much greater bacterial flora is no more efficient in decomposing nitrogenous and non-nitrogenous organic substances added to it.

2. A large proportion of the soil fungi are killed as a result of partial sterilization. This dead material with the bodies of destroyed protozoa and other micro-organisms still further increases the amount of energy made available in the soil.

3. The rapid increase in the numbers of micro-organisms in the soil is at the expense of the organic matter made available. This is further confirmed by the fact that the course of development of fungi results in a curve somewhat similar to that given by the bacteria, although the rise in the curve may take place at a later date. The numbers of fungi, however, may not indicate the period of maximum activity which may have been passed already. Large numbers of fungi, shown by the plate method, may be due to abundance of spores. Where active growth of fungi takes place, due to available nutrients, spore formation may be greatly delayed. The vegetative mycelium, however extensive, may show much smaller numbers than when spore formation occurs.

4. The carbon and nitrogen are present in the soil in a certain proportion, depending upon the physical and chemical condition of the soil; when the carbon compounds are decomposed as sources of energy by the bacteria and actinomycetes some of the nitrogen is left as a waste product. The carbon-nitrogen content of the soil and of the bodies of the bacteria, actinomycetes and fungi combined with the economic utilization of the carbon by these three groups of organisms, explain why the development of the first two groups of organisms will bring about the liberation of nitrogen from the soil organic matter to a greater extent than the development of the fungi.

5. The actual amount of ammonia formed in partially sterilized soil is determined not by the numbers of bacteria and fungi developing in the soil, but by the abundance of organic matter. The course of development of numbers of bacteria in the soil seems to be influenced by the course of development of the fungi. The course of development of actinomycetes depends upon the method used in bringing about the partial sterilization of the soil as well as by the organic matter content of the soil.

6. The protozoa are suppressed in partially sterilized soil, but become active again long before the bacterial numbers drop down very markedly.

7. The more rapid the rise in bacterial numbers and the greater the maximum, the sooner will the fall set in. This is exactly true of the numbers of fungi. These phenomena are results of the amount of available plant food in the soil.

8. The phenomena observed as a result of partial sterilization of soil, namely the rise of bacterial numbers and ammonia accumulation are explained by (a) the change in the physical condition of the soil, especially the soil colloids, (b) the change in chemical condition, especially modification of soil organic matter, making it more readily available; (c) the destruction of a large number of soil micro-organisms, especially the fungi and protozoa, making their bodies available as sources of energy for the surviving micro-organisms; (d) the change in balance of the microbiological flora of the soil (all of these favor greatly the development of the bacteria); and (e) the fact that bacteria use organic nitrogenous substances (as well as other carbon compounds) very uneconomically as sources of energy and liberate a great deal of ammonia as well as phosphates and other minerals stored away in the soil organic matter as waste products.

9. These results apply to normal soils. It is possible that under certain conditions other phenomena become controlling factors. We need only mention soils infested with fungi causing plant diseases or sewage farming and greenhouse soils, where protozoa may become controlling factors.

Acknowledgment

The writer wishes to thank A. J. Mangelsdorf, C. W. Carpenter, Douglas A. Cooke and D. M. Weller for their cooperation in the above study.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1932, TO JUNE 16, 1932

Date	Per Pound	Per Ton	Remarks
Mar. 16, 1932	2.765¢	$55.30	Porto Ricos, 2.78, 2.77, 2.76; Philippines, 2.76; Cubas, 2.76, 2.75.
" 17	2.75	55.00	Porto Ricos.
" 18	2.71	54.20	Porto Ricos, 2.72, 2.71; Philippines, 2.72, 2.71, 2.70.
" 21	2.755	55.10	Philippines, 2.76, 2.75.
" 22	2.745	54.90	Cubas, 2.75; Philippines, 2.74.
" 24	2.735	54.70	Philippines, 2.74, 2.73; Cubas, 2.73; Porto Ricos, 2.73.
" 28	2.725	54.50	Philippines, 2.73; Porto Ricos, 2.72.
" 29	2.695	53.90	Porto Ricos, 2.70, 2.69; Philippines, 2.70.
" 30	2.69	53.80	Philippines.
" 31	2.685	53.70	Philippines, 2.69, 2.68.
April 1	2.675	53.50	Philippines, 2.69, 2.66; Porto Ricos, 2.69.
" 5	2.65	53.00	Porto Ricos, 2.66, 2.65, 2.64; Philippines, 2.66.
" 6	2.605	52.10	Porto Ricos, 2.60; Philippines, 2.61.
" 7	2.60	52.00	Philippines, Porto Ricos.
" 8	2.66	53.20	Philippines.
" 13	2.605	52.10	Philippines, 2.60; Porto Ricos, 2.61.
" 14	2.64	52.80	Porto Ricos, 2.63, 2.65.
" 15	2.65	53.00	Cubas, Philippines, 2.65.
" 18	2.63	52.60	Porto Ricos, Philippines.
" 19	2.61	52.20	Porto Ricos.
" 22	2.63	52.60	Porto Ricos, Philippines.
" 23	2.65	53.00	Porto Ricos.
" 27	2.64	52.80	Philippines, 2.63; Porto Ricos, 2.65.
" 28	2.62	52.40	Porto Ricos, Philippines.
May 2	2.60	52.00	Philippines, Porto Ricos.
" 3	2.605	52.10	Philippines, 2.61; Porto Ricos, 2.61, 2.60.
" 4	2.60	52.00	Porto Ricos, Philippines.
" 5	2.58	51.60	Porto Ricos, Philippines.
" 7	2.58	51.60	Philippines.
" 10	2.63	52.60	Porto Ricos, 2.62, 2.63, 2.64; Philippines, 2.62; Cubas, 2.62.
" 11	2.60	52.00	Cubas.
" 13	2.59	51.80	Porto Ricos.
" 14	2.58	51.60	Porto Ricos.
" 16	2.585	51.70	Porto Ricos, 2.59; Philippines, 2.58.
" 17	2.58	51.60	Porto Ricos.
" 19	2.60	52.00	Philippines, Porto Ricos.
" 20	2.58	51.60	Philippines.
" 27	2.60	52.00	Porto Ricos, Philippines.
" 31	2.57	51.40	Philippines.
June 3	2.60	52.00	Cubas, Philippines.
" 6	2.62	52.40	Porto Ricos, Philippines.
" 8	2.62	52.40	Porto Ricos.
" 9	2.65	53.00	Philippines.
" 10	2.65	53.00	Philippines.
" 13	2.71	54.20	Philippines, 2.70; Porto Ricos, 2.70, 2.72; St. Croix, 2.70.
" 14	2.75	55.00	Porto Ricos, Philippines.
" 16	2.795	55.90	Porto Ricos, 2.79, 2.80; Philippines, 2.80.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXVI FOURTH QUARTER, 1932 No. 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Plantation Jobs for Local Young Men:

A matter of fact discussion of the opportunities for local young men to find employment on sugar plantations brings out statistics on the number of openings likely to be available, and makes comparison with an estimate of the number of those attaining working age. This indicates the need of some outside source of labor for several years to come. A practical means of introducing young men to the work of the plantations has been developed through the "citizen's training gang." We are told that the response of the young men to the opportunities thus offered is gratifying. The young men of Hawaii are evidently to take up the work that Hawaii has to offer them, and one way of satisfactorily introducing them to it is outlined in this article.

Improvement of Field Experiments:

The large difference in the average yields of two similarly treated series of plots, closely adjacent, shows the necessity for greater care in the selection of a representative area for field experiments. A study and consideration of the factors that were concerned with the greater yield variations of experimental plots during the last three crops indicates opportunities that are still open for the improvement of our field experiments.

New Irrigation Methods:

Information on new irrigation methods is given in the form of a discussion that took place at the last annual meeting of the Association of Hawaiian Sugar Technologists, together with the introductory paper on which the comment was based.

Sunlight Hours in Hawaii:

The effect of the time of year, the angle of the slope of the cane field, and the direction of the slope of the field, on the intensity of sunlight are dealt with and are explained by diagram.

Beri-beri:

Beri-beri is a disease which continues to take its toll from the energy and life of our population through ignorance of simple nutritional precautions which are pointed out in a bulletin issued by the Queen's Hospital.

Composition of a Cane Crop:

This paper points out that a crop generally consists of cane of different age groups, which are materially different from each other both in quality and total quantity. It also shows that the average juice quality of a crop is a composite between the stalks of different ages, and within the same stalk this quality is also a composite between the dead-leaf and green-leaf parts. It is suggested that only through these conceptions of the elements of a crop can we hope to gain a clearer understanding of the interrelated problems of cane tonnage and quality.

Soil Moisture and Cane Elongation:

The magnification of the rate of growth of a cane plant by means of a balanced mirror has permitted precise observations upon the effect of soil moisture upon cane elongation. Results of extended studies with this device indicate that complete growth cessation sets in when the soil moisture is reduced to the permanent wilting percentage, as has been previously suggested. Moreover, the period of retarded growth preceding complete cessation seems to be associated with the difference in the demands for transpiration during the day and night. A similar device for use in the field is under construction.

Plantation Jobs for Local Young Men*

By E. W. Greene
Manager, Oahu Sugar Company, Ltd.

The members of your Association and the members of the Hawaiian Sugar Planters' Association are, and for many years have been, deeply interested in employing in the sugar industry as many as possible of the young men who are growing up in Hawaii.

Leaders of the industry at various times have clearly set forth their guiding policy in matters pertaining to employment, of which the following quotations are examples:

Quotation from the address of A. W. T. Bottomley in 1930 as retiring president of the Hawaiian Sugar Planters' Association:

At the beginning I desire to say with all the emphasis that can be carried into a positive statement that there is no employer in the sugar industry, nor, I believe, in any other responsible and important industry of the Territory, who does not earnestly desire to employ citizens of Hawaii, in preference to those who come from outside our boundaries, be they citizens of the United States, Filipinos or aliens.

With equal emphasis I assert that preference is and always will be given to the employment of citizen labor and present residents of our Territory above all others, such preference and employment being always subject to the suitability of those available for the tasks in question and to their readiness and willingness to undertake them.

Quotation from the address of F. C. Atherton in 1931 as retiring president of the Hawaiian Sugar Planters' Association:

As you all know, definite assurances have been given to these people (i. e., young people growing up here), the great majority of whom are citizens, that they will be given every opportunity for employment, and as far as practicable in skilled and semi-skilled positions as same are available, and they are qualified to fill them.

There are jobs available every year on our sugar plantations; there are young men growing up in Hawaii to working age each year; there is a sincere desire on the part of those responsible for the operation of the sugar industry to attract local young men to plantation jobs; and there is a sincere desire on the part of a great majority of local young men to get and keep steady jobs. All of these statements are true and still we have difficulty in bringing together the local young man and the plantation job which is available for him provided he is ready and willing to take it.

Why should this problem exist? Demagogic political office seekers, striving to gain votes by any means, assert that it is because the plantations want "cheap Filipino labor," while other misguided, misinformed or designing persons say vaguely that it is because we have not tried honestly to make agricultural jobs and rural life attractive to local young people. Such statements and others of

* **Presented at eleventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October, 1932.**

similar purport may properly be dismissed with the emphatic statement that they are untrue.

I feel sure that your president in assigning this subject to me had the same thought in mind which I had in accepting it, namely, that no useful purpose would be served by taking up your time in refuting untrue and unfair statements such as those quoted above.

It is, however, worth while to analyze the problems involved in this matter, to show some of the accomplishments which mark the progress thus far made toward their solution, and to attempt to formulate constructive lines for future work.

As members of this Association, closely identified with the work of the sugar plantations of Hawaii, we know that the problem of bringing together the local young man and the plantation job has its roots in such matters as the following:

(a) The distribution of population in relation to the distribution of available jobs;

(b) The co-operation of the schools and industry;

(c) Reasonable provision for training and guiding young men through the period of adjustment to the change from school to work;

(d) The provision of every reasonable opportunity for local young men who have taken plantation jobs, to qualify for, and when qualified to receive, as openings occur, promotion to skilled, semi-skilled or "preference" jobs, or other opportunities for advancement within the organization, for which the person in question may be duly fitted;

(e) Attitudes toward plantation jobs of some among the local young people, their parents and members of the plantation organization with whom they come in frequent contact;

(f) Various social factors.

We may first consider the distribution of population and employment, using as bases the figures of the United States Census of 1930 and data collected by the Hawaiian Sugar Planters' Association.

TABLE I

Total Population
(Figures from U. S. Census, 1930)

Territory of Hawaii:	
Population, 1930	368,336
Population, 1920	255,912
Increase	112,424
Increase over 1930	43.9%
City District of Honolulu:	
Population, 1930	137,582
Population, 1920	83,327
Increase	54,255
Increase over 1920	65.2%

The population of the city district of Honolulu in 1930 had increased by 65.2 per cent over the census figure for 1920, while the population of the entire Territory during the same period had increased by 43.9 per cent. The population of the city district of Honolulu was 32.6 per cent of the entire Territory in 1920, and 37.4 per cent of the total in 1930. There has been during the decade an extremely rapid increase in the number as well as the proportion of city dwellers.

TABLE II

Persons Gainfully Employed, by General Division of Occupation—10 Years of Age and Over (Figures from U. S. Census, 1930)

Occupation	1930 Census Number	1930 Census Per Cent of Total	1920 Census Number	1920 Census Per Cent of Total	Change in Number Engaged Increase	Change in Number Engaged Decrease
All occupations	154,270	100.0	111,882	100.0	42,388	
Agriculture, forestry, and animal husbandry	65,692	42.58	56,244	50.30	9,448	
Manufacturing and mechanical industries	21,028	13.64	18,194	16.20	2,834	
Public service (general)	21,387	13.87	6,282	5.60	15,105	
Trade	13,141	8.52	7,343	6.50	5,798	
Domestic and personal service	12,595	8.16	8,466	7.60	4,129	
Transportation	10,780	6.98	7,781	7.00	2,999	
Professional service	8,533	5.53	4,117	3.70	4,416	
All other	1,114	.72	3,455	3.10	....	2,341

	1930 Census Total	1930 Census Male	1930 Census Female	1920 Census Total	1920 Census Male	1920 Census Female
Total population	368,336	222,640	145,696	255,912	151,146	104,766
Gainful workers	154,270	136,460	17,810	111,882	97,619	14,263
Gainful workers in per cent of total population	41.9	61.3	12.2	43.7	64.6	13.6

There has been a marked increase during the ten-year period in occupations which are largely in the city districts of Honolulu and Hilo, such as Public Service, Trade, Manufacturing, Domestic and Personal Service. These five classifications account for an increase of 32,282 persons, or 76.2 per cent of the total increase of 42,388 persons, gainfully employed.

The number in agriculture, forestry, and animal husbandry, in which 42.58 per cent of all persons gainfully employed were still engaged in 1930, had increased by only 9,448 individuals during the ten years. Therefore, although almost one-half of all people at work in 1930 were engaged in agriculture, forestry, and animal husbandry, they account for only 22.3 per cent of the increase in total workers during the preceding ten years.

The decade 1920 to 1929 was a period of unusual expansion and activity in the cities, especially Honolulu. Public and private building of all sorts was carried on at an unusual rate, governmental service was enlarged in scope, the canning industry expanded rapidly, and transpacific shipping increased considerably, bringing in its train the growth of various lines of business. This rapid develop-

ment has been the cause of the unusual increases in city population and employment which have occurred during the decade. Numbers of people from the rural districts were attracted to the city, and they as well as most of the young people in the city who attained working age during this period found employment in city work, many of them in contracting and other lines where work is intermittent. The ambitions of many young people growing up in the rural districts were drawn to city employment, which, due to the unusual conditions above mentioned, was made to appear attractive.

The present conditions have not only caused unemployment among city workers, but have made it apparent that even after the present situation has passed some part of the young men now growing up in the city will probably have to seek employment in the rural districts in agricultural work if they are to find steady employment.

Meanwhile the number of employees on sugar plantations has remained about constant during the past few years, as shown by the following figures:

TABLE III

Employees on Sugar Plantations
(Figures from H. S. P. A. Records)

Year	Number of Employees
1928	54,437
1929	53,587
1930	53,304
1931	53,960
1932 (7 months)	53,253

EMPLOYEES ON SUGAR PLANTATIONS IN RELATION TO TOTAL GAINFULLY EMPLOYED

Total gainfully employed (U. S. Census, 1930)	154,270
Employees on sugar plantations (H. S. P. A. Records, 1930)	53,304
Employees on sugar plantations in per cent of total gainfully employed	34.6

CITIZEN EMPLOYEES ON SUGAR PLANTATIONS
(Figures from H. S. P. A. Records)

Average for first seven months of 1932	8,391
Citizen employees in per cent of total employees, for first seven months of 1932	15.8

The sugar industry employs directly on plantations more than one-third of all gainful workers in the Territory. Citizens in the number of 8,391 constituted 15.8 per cent of all plantation employees as an average for the first seven months of 1932, and their numbers are steadily increasing.

The records of the Hawaiian Sugar Planters' Association show that for the past few years there have been between 12,000 to 14,000 departures per annum from pay-rolls of all sugar plantations. However, a large number of these represent transfers from one plantation to another. The net requirements of sugar plantations are probably between 6,000 and 8,000 new employees a year as

replacements of those dropping out of the working community for all causes, including return of Filipinos to their native islands.

How many local young men will be available as potential candidates for these replacements of vacancies, provided they are ready and willing to take the vacant jobs? The census figures give the total number in each age group, of whom, of course, only a part could be considered as available for plantation work.

TABLE IV

Population by Year of Age in 1930

Age in Years	Male	Female	Total
1	4,948	4,702	9,650
2	4,896	4,802	9,698
3	5,087	5,037	10,124
4	4,708	4,427	9,135
5	5,257	5,134	10,391
6	4,911	4,936	9,847
7	4,672	4,484	9,156
8	4,605	4,415	9,020
9	4,449	4,256	8,705
10	4,374	4,092	8,466
11	3,913	3,809	7,722
12	3,850	4,024	7,874
13	3,698	3,495	7,193
14	3,400	3,387	6,787
15	3,268	3,115	6,383
16	3,175	3,069	6,244
17	3,145	2,850	5,995

In considering plantation jobs, we are concerned with the males shown in the tables, and with their distribution as between rural and city districts. The census does not show the residence by single years of age, but does show it for an age group as follows:

TABLE V

Distribution by Counties and City Districts of Population, Ages 5-14

	Total Population Ages 5 to 14 Inclusive		
	Male	Female	Total
Hawaii (less Hilo)	6,433	6,162	12,595
Oahu (less Honolulu)	6,488	6,256	12,744
Kauai	3,932	3,899	7,831
Maui	6,748	6,780	13,528
City District, Honolulu	16,800	16,510	33,310
City District, Hilo	2,603	2,550	5,153
Totals	43,004	42,157	85,161

During the ten-year period in which the boys who were from 5 to 14 years old in 1930 grow up to working age there will be a total of 4,300 a year, of whom

1,680 are in the city district of Honolulu and 260 are in Hilo, making a total of 1,940 a year in cities, and 2,360 a year in rural districts.

It is, of course, a fact that in no one year would all the boys of one age go to work, since they would start at various ages from 15 up to over 20. However, the variation between yearly age groups over a period of a few years is so small that we may probably assume without grave error that the total number of young men who will enter work in any one year will be about equal to the mean number a year for the period.

If 60 per cent, which is a proportion never yet approached, of the 4,000 or so young men who enter work each year were to go onto plantations, this would be 2,400 a year, or about one-third of the number of replacements normally required, as shown by the records of the past few years. This number, however, would involve a considerable movement of city boys to the country, a development which cannot be forced and which even with gradual growth presents difficulties either in Hawaii or elsewhere in the United States.

The foregoing figures and statements have shown that there is no dearth of potential openings for our 2,400 new entrants upon work, provided they are ready and willing to take the jobs which are available. There are, however, real problems due to the distribution of population in relation to the distribution of jobs by localities.

Table II (above) shows that for several years the number of employees on sugar plantations has been between 53,000 and 54,000. How are the 53,000 jobs distributed by classifications of work? The following table, which gives this information for an irrigated plantation, gives an indication of the answer to this question:

TABLE VI

Average Distribution of Employees on an Irrigated Sugar Plantation

	Number	Per Cent of Total
Field work, automotive department, railroad and experimental department	2,355	77.6
Factory, electrical department, laboratory and shops	302	10.0
Pump department	113	3.7
Carpenter and building department	84	2.7
Civil engineer's department and mountain water system	98	3.2
Office	5	.2
All others	80	2.6
Total	3,037	100.0

Dividing the figures in another way it is found that there are a total of 490 skilled, semi-skilled and "preference" or "prestige" jobs other than long term cultivation contractors, 915 long term contractors, and 1,632 in all other labor classifications.

It will be noted that almost 80 per cent of the jobs are in the field and its associated departments.

Assuming a somewhat similar division for the 53,000 employees of all plantations, there would be about the following numbers in jobs:

Field work and related departments	41,500
Factory, shops, etc.	5,300
Water supply engineering, construction and miscellaneous	5,300
Office	110
All others	790
Total	53,000

The division of the new openings for replacement jobs will not correspond proportionately to the above classification by kinds of work, because the turnover is always highest among the rank and file of manual labor, and decreases rapidly and progressively through to the semi-skilled and skilled employees, and those in the supervisory grades.

If we assume 7,000 vacancies a year it is probable that about 5,700 of them would occur in field labor and cultivation contractors, 700 in all other labor, and 600 in semi-skilled and skilled jobs. However, a large part of the semi-skilled and skilled jobs must necessarily be filled by promotion of those citizens who have qualified for them, usually by starting at the bottom as a laborer, or as one of the limited number of apprentices who can be taken on for the various trades.

Therefore, of the 2,400 local young men we have heretofore deduced as being the maximum we might think of as entering plantation work in each of the next ten years, only a few of the best qualified could hope to enter immediately upon "preference" or "prestige" jobs, and the great majority would start at the bottom in the field.

An attempt has been made in the foregoing pages to present realistically the facts pertaining to the distribution of population and of employment opportunities, with special reference to sugar plantations.

It is apparent that any attempt to deal with the employment of local young men in material numbers on the basis of their entering only upon "preference," semi-skilled or skilled jobs when beginning work is foredoomed to failure because of the very limited number of such "preferred" openings, of which only a few could be filled by a beginner.

It is equally apparent, on the other hand, that the numbers of local young men who will be available within the next few years are utterly inadequate to supply all of the replacements required by sugar plantations, even if all of them were ready and willing to take the jobs available.

Therefore it will be necessary to bring together the local young man and the plantation job which is available for him, recognizing that it will be necessary in most cases to start at the bottom in field work. If our program of cooperation is not one which has a reasonable possibility of bringing this about, then it is foredoomed to failure. The progress which has been made, however, indicates that there is cause to feel confident that in time it will be increasingly successful.

The closer cooperation which is developing year by year between the schools and the agricultural industries has been productive of good results which will

increase as time goes on. School and home gardens or similar projects have interested children in growing things. Smith-Hughes classes in vocational agriculture when properly planned and carried on have usually been successful in acquainting boys with the nature of field work and giving preliminary training in its performance. A number of young men are successfully employed on plantations today because their interest in the work was aroused in such classes. A further development is the experimental Continuation School for boys regularly at work which is being carried on this year in one plantation community. Each of the boys enrolled attends school for 4 hours on one day a week, which it is planned to continue for two years.

Valuable as such work carried on jointly by the schools and industry unquestionably is, it cannot eliminate the necessity for adequate provision for training and guidance of boys and young men during the period of adjustment from school to work through which they pass in their first few months in regular employment, especially in field work.

Such a training program which has worked out well in practice is the formation of a "Citizen's Training Gang," which is entered by all local young men newly employed for field work. Here the youths work in the regular group piece work gang organization, at the usual piece work rates, and all in the gang share on an equal basis in the group earnings.

The Citizens' Training Gang works over the whole gamut of field operations, so that there is opportunity to learn how each of them should be done in order to make a good job. It is especially important to select the right type of luna, having qualities of leadership, fairness, thorough knowledge of the work, ability to teach how the work should be done, and a genuine interest in the boys and the objects of the training work. The young men in training are in constant, daily contact with the luna, and his attitude toward the work, and his manner of dealing with the youths under his charge will have a great influence on the attitude developed by them as well as their progress in learning the work.

The maintenance of order and discipline and insistence on performance of work up to an acceptable standard should be the same as in any gang, because there is no use in postponing the time of realization that work is serious business to be seriously done. However, in administrative relations with members of the Training Gang it should be borne in mind that they are youths in training and not mature men.

The sincere and continuous interest of the head overseer and section overseers in the training program is essential to its success.

After a stay in the Citizens' Training Gang varying from a few months to a year, depending upon the age and physique of the youth and his aptitude in learning the work, he goes into a long term cultivation contract or one of the field group piece work gangs, fully able to hold up his end of the work, often better versed in the work than his fellow-workers in the gang to which he goes, and sharing in the group earnings on a "man-basis." Usually his morale is high, and there is an excellent possibility that ~~he will~~ stick and get ahead in his work.

Consider as an alternative the situation of the inexperienced youth who, newly entering work, goes directly into a field gang without preliminary training. The

work is strange to him and he is awkward in performing it, probably being the butt of joshing by his fellow workers. It is a jolting jump from the schoolroom to work under any circumstances, and more so if, due to some attitude, he may have absorbed in school, he at first considers the work beneath that which he should do. He has to work for some time at a "boy-differential" in earnings. Except in the case of a few of the most capable and determined youths, there will be a rapid lowering of morale, a development of dissatisfaction and the probability that he will quit his job and may possibly wind up a loafer or worse.

Some may say that the individual should develop his own initiative and determination to work, and manage to get his own training. Theoretically that may be true. Practically we want results in terms of numbers of local young men successfully established in plantation jobs, and we should take the necessary steps to go more than half way in bringing together the local young man and the plantation job.

The plan of training described above is one which has worked out in practice, but it is recognized that considerable variation may be desirable in fitting the methods to the conditions existing on various plantations.

The important thing is that there shall be a systematic plan of training and guidance through the period of adjustment from school to work, and that it be given the continuing interest and supervision of the plantation management and staff.

The local youths who have qualified by ability and demonstrated willingness to work at the starting jobs, usually in the field, which are available, should be promoted to the skilled, semi-skilled and "preference" jobs *for which they are fitted,* whenever vacancies occur in such promotional jobs. It is, of course, understood that the local young man in order to secure promotion must be capable of filling the advanced job, for which he must have qualified by his past work record and length of service. Personnel records which can be used for reference in such cases are advisable.

No one would advocate displacing capable and faithful semi-skilled or skilled workers to make way for local young men. However, when a vacancy occurs in such a job in any department, every effort should be made to fill it by promotion of a local citizen who has qualified for it, and, if possible, by one who has started at the bottom in the field. Earned promotions, made according to a consistent plan, are a powerful magnet in attracting other local young men to enter plantation jobs.

The attitudes toward plantation work of some of the young people, some of their parents, some school teachers and some in other elements in the community add to the problems involved in bringing together local young men and the plantation jobs which are available for them. Attitudes cannot be corrected by condemnation. They can only be changed by a long and patient course of continuing to carry on our affairs in such a way that the right attitude should be developed thereby in any reasonable person, and by combating and correcting wherever they are found erroneous statements or ideas which might contribute to the formation of wrong attitudes. More often than not, it will be found that an attitude of

prejudice against plantation work is due to ignorance of working and living conditions on plantations.

While mentioning the problems created by the attitude of some of the young people and others it should be borne in mind that many of them have an excellent attitude toward plantation work, especially if there is the proper method of approach to them.

I have dwelt in some detail upon the phases of these questions which deal with the young citizen in his relationship to employment in general and sugar plantation work in particular, and some of the advantages which will accrue to the individual and the community as more local young men take plantation jobs, have been pointed out either directly or by inference.

In addition, I want to say emphatically that it is to the advantage of the individual plantation and of the sugar industry as a whole to have as many local citizen employees as possible, and to make every reasonable effort to attract them to the jobs which are available, train them in the work, recognize long service, and, as promotional openings occur, give them preference to the full extent of their qualifications.

The progress which has been made in the industry as a whole shows what can be accomplished by continued effort during the next few years.

It has been clearly demonstrated that local young men in considerable and growing numbers will enter the jobs which are available for them on plantations.

The statistics herein presented to you show that even if a majority of the local young men who attain working age each year should go into sugar plantation work there would still be a shortage in the normal replacement requirements to be made up from other sources in order to carry on the work of the plantations.

The greater number of openings for beginners in plantation work are in field labor, and therefore any effective plan for attracting local young men to plantation work must be laid out accordingly.

Adequate programs for training and for promotion on merit are essential.

The sugar industry of Hawaii employs directly on plantations over one-third of all the workers in all lines of business in the Territory. Having such a large part in the employment possibilities of our local citizens, and recognizing that local young men make excellent workers, it is natural that those responsible for the sugar industry should devote much thought and effort to the stimulation of employment of those who are ready and willing to take the jobs which are available.

Plantation work offers steady, year-round employment at good pay with good working and living conditions. Local young men make highly desirable employees for plantations. The continuation of efforts directed along right lines toward bringing together the local young man and the plantation job will be increasingly successful and will be advantageous both to our young citizens and to the sugar industry of Hawaii.

Improving Field Experiments

By Ralph J. Borden

The value of any statistical method as an aid in the interpretation of results from a field experiment can only be as great as the accuracy and representativeness of the yield figures upon which the method is to be used. No analysis of these yield data, in the office, can correct for the agronomic errors that have been made and the effect of which is already a part of the field results that are submitted for interpretation. High odds that a yield from one treatment is superior to another are of no practical value unless such odds have been determined from accurate data that represent conditions where our recommendations are to have practical field application. With a test properly installed on a truly representative area, our efforts must all be directed in an attempt to secure reliable yield figures that we may interpret.

Representative Areas

Critical studies of field experiments indicate that we can perhaps afford to put more time upon the selection of an area for a field experiment that will truly represent the larger unit of land area to which the problem we are to test will have its practical application. When the yields of the 60 plots of the Hilo Blank Test 58B-1932 were being studied, we were much impressed by the fact that the average yield for the 30 plots in a column adjoining the flume was 97 tons, while the average for 30 adjacent plots of the inner column, that was not 50 feet from the flume, was only 82 tons; in all except one case, 29 out of 30, the plots of the outer column surpassed the yields of the adjacent plots of the inner column. We seriously question the possibility that this outer column of 30 plots represents the average conditions of the field in which it is located. Hence some issues that might be scheduled for testing on the area occupied by this outside column, could not be expected to give us a reliable answer for application to the field. For instance: 200 lbs. of nitrogen might be found to be the economic limit for the strip of 97-ton cane, yet it is conceivable that this amount of nitrogen could be still further increased, with profit, on the 82-ton cane of the inner column.

The situation just described, prompted us to examine our field experiments for similar conditions, and we found indications that we were not dealing with an exceptional occurrence. For instance, let us look at the following:

(1) Experiment 26-30 at Hakalau: 15 plots bordering the trail averaged 55.4 tons of cane. This may be compared with 15 plots, that had the same total treatment, located in an inner column, that averaged 69.5 tons.

(2) Experiment 9-31 at Pepeekeo: 10 plots along the road averaged 74.8 tons; 10 inner plots that are directly comparable averaged 66.5 tons.

(3) Experiment 76-32 at Kilauea: 7 plots in a roadside column averaged 47.3 tons; the adjacent 7 comparable plots inside the field averaged 58.7 tons.

(4) Experiment 2-31 at Kaiwiki: 12 plots on the upper side of the road averaged 68.7 tons; a similar group on the lower side averaged 55.7 tons.

(5) Experiment 6-31 at Laupahoehoe: 15 plots bordering the gulch averaged 65 tons while a comparable group just inside the field produced 82 tons.

(6) Experiment 25-31 at Maui Agric. Co.: The 15 H 109 check plots nearest the camp road averaged 91 tons; the 16 H 109 checks in the inside half of this area averaged 83 tons.

(7) Experiment 44-32 at H. C. & S. Co.: 7 H 109 check plots in one level ditch averaged 84.4 tons; 7 similar check plots in the next-but-one level ditch averaged 102.7 tons.

Further evidence of variation, which makes one wonder which test condition is representative of the major area of the field where the test is located, is offered when we compare the average yield of one series of plots with the average of a similar and comparable series, the two groups being located very close together in the same field. For instance:

(1) In Field 27 at Pepeekeo, a group of 10 "X" plots in Experiment 9 averaged 68 tons of cane, while in the adjacent area, the 10 "F" plots of Experiment 12, that had received identical treatment as the "X" plots of Experiment 9, averaged 77 tons.

(2) In Field 18 at Pepeekeo, a group of 9 "D" plots of Experiment 16 averaged 80 tons of cane; a group of 9 "G" plots in Experiment 17 adjoining, averaged 68 tons. Both groups had received identical treatment. In this same contiguous area 9 "B" plots from Experiment 15 gave 84 tons, and 10 "X" plots from the adjoining Experiment 18 averaged 74 tons. All four of these series of plots had been similarly treated.

(3) In Field 14 at H. C. & S. Co., a group of 7 "C" plots of Experiment 6 averaged 68 tons. This may be compared with a group of 7 "G" plots of Experiment 7, which were similarly treated and located in adjacent level ditches, and which produced an average of 82 tons.

(4) In Field G at H. C. & S. Co. a group of 7 "C" plots from Experiment 11 gave 85.6 tons, as compared with a similarly treated group of 7 "G" plots of Experiment 13 that gave 72.6 tons.

(5) In Field O-8 at Pioneer, a group of 9 "C" plots in Experiment 25 averaged 89.7 tons and a group of adjacent plots, of an NPK test, that had received similar treatment, averaged 76.7 tons.

(6) In Field B1 at Pioneer: 6 "E" plots of Experiment 32 at 84.3 tons had been treated just the same as a group of 6 NPK plots from the adjoining Experiment 33, which made an average yield of 97.8 tons.

From the foregoing examples of differences between various series of plots on closely adjacent areas, one sees the necessity for a careful study and recognition of conditions that might make for such differences, for we must insist that the area selected for our experiments be representative of the average conditions for which it is planned. Thus, we are led into a study of the probable reasons that underlie and cause the plot yields to vary to any considerable extent.

Analyzing the Greater Variations in Plot Yields

In an effort to find more definite evidence of possible reasons for yield variation in field tests, we have examined the 1930, 1931, and 1932 experiments conducted by the Station, and have tabulated all plot yields, that varied more than plus or minus 10 per cent from their treatment average, under the following headings:

1. Border effect.
2. Shape of plot.
3. Adjacent to crop cane.
4. Possibly mixed.
5. Definite fertility zone.
6. Undetermined.

(1) *Border Effect:* Under this heading, we have placed those plots whose deviation of more than 10 per cent from their treatment mean, we felt reasonably certain was caused by their position on or proximity to a road, trail, gulch, ditch, waste area, or to some other factor that would give to their perimeter, a different exposure from other plots in the test area, which might well be responsible for the yield that was "wild" or considerably different from the average.

(2) *Shape of Plot:* Here we have grouped those plots that are wedge-shaped, triangular, or which have irregular outlines, and also plots that carry an extra short (hapa) watercourse. Errors of area measurement or errors due to separating cane at harvest are indicated in such cases. Perhaps these odd-shaped plots are made necessary by changes in contour and such changes carry differences in natural fertility. Perhaps the relative amount of border cane in the average and the abnormal yielding plot, as indicated by differences in the ratio of a plot's perimeter to its acreage, is responsible for the variations we find.

(3) *Adjacent to Crop Cane:* This classification was added as an afterthought when we found that a large number of the so-called "wild" plots were adjacent to crop cane, and there were no other apparent reasons for the deviation from the normal. The reason for same is debatable. Where the situation occurs at the end of a series of test plots, it is possible that the loaders accidentally mixed up the crop cane and the experiment cane of the adjoining plot, perhaps during a moment's suspension of watchfulness on the part of the man checking the loading. Where the end plot of the test area has a high yield, there is a possibility that the plantation fertilizer gang overstepped their bounds and gave the test plot an extra dose of fertilizer. Where the situation is an internal one, it is possible that the original reason for having a plot of crop cane inside the test area may be the cause of the variation of the adjacent plot of experiment cane. For instance: an outcropping of rock within the test area would probably result in a plot of crop cane therefor; it is quite possible that this rock formation may extend under the surface of the ground and affect an area to a considerably larger extent than surface inspection reveals.

(4) *Possibly Mixed:* Whenever we found two "wild" plots adjacent, and one of them was high while the other was low, providing other plots in proximity were normal, we suspect that the cane grown on the two plots has been mixed before it was weighed. Perhaps there is another answer to such a situation, when there is an abrupt change of contour.

(5) *Definite Fertility Zone:* Very early in the study, we recognized the existence of a definite zoning of groups of high and of low yielding plots. We soon found that this was the greatest factor that we would have to deal with. Unfortunately, this zoning is not a factor over which we have the same degree of control that we can have over the four preceding factors, and we are in need

of a practical technique that will locate it. Blank tests have been suggested, to precede the experiment, and they do offer some promise. Soil borings, to determine the uniformity of soil characteristics have been used to advantage in Louisiana. Ample replication of plots does much to reduce the effect on a treatment average that a few plots in a zone of low or of high fertility would have, if there was an uneven distribution of this fertility between the treatments.

(6) *Undetermined:* Under this heading we have placed all other deviating plot yields that were not specific errors and which we could not satisfy ourselves to put into one of the preceding classifications. They form a large part of our total number of "wild" plots and are not understandable. We may only guess as to reasons for their being so different from the average.

Summarizing now, we have found a total of 3155 plot yields that deviate by more than 10 per cent from their treatment average, These are here grouped under the six headings that have just been discussed.

(1)	Border effect	153 plots or roughly	5 per cent of the total;
(2)	Shape of plot.............	87 plots or roughly	3 per cent of the total;
(3)	Adjacent to c.c............	277 plots or roughly	9 per cent of the total;
(4)	Possibly mixed	117 plots or roughly	4 per cent of the total;
(5)	Definite zones	1987 plots or roughly	63 per cent of the total;
(6)	Undeterminable	534 plots or roughly	16 per cent of the total.

The border effect and the effect of shape are very definitely associated with the "wild" plots of irrigated cane. None of the other reasons for deviation can be definitely set down against the irrigated fields to any greater extent than against the non-irrigated fields: the fertility zoning particularly, being just as distinct on both types of cane.

Summary

Opportunities that are still open to the plantation agriculturist to improve his experiments, are to eliminate some of the possibilities of having plot yields in his test areas that vary widely from the average.

Guard against abnormal yields from border effect by not including in the test, plots that have a border exposure that is materially different from other plots in the test area. Preferably, border the test area with similar conditions: surround it with cane.

As far as possible, avoid areas that require odd-shaped plots. If it is necessary to take an area that includes a few such plots, plant and harvest them as crop cane and not as one of the replicates of a treatment.

If necessary to have plots of crop cane within the limits of the experimental area, be sure that such crop cane area extends over a sufficiently large space to exclude any underground influence from the factor that was responsible for having an inside plot of crop cane.

Assume control of all fertilizing operations on the crop cane adjacent to experimental areas as well as on the experiment itself.

Increase the supervision of cutting and loading and take every precaution to prevent possible mixing. Be especially alert at the borders of the test area where the experiment cane adjoins the crop cane.

Spend more time *in the field* before installing the experiment, using the old and devising new methods for locating, and then avoiding, abrupt changes in fertility, and in getting actual rather than assumed uniformity for the treatments.

New Irrigation Methods*

By L. D. Larsen

The past two years have experienced a more widespread change in irrigation practices than the previous twenty; and the next two years, from all indications, will see still more.

Other field practices have undergone a gradual revolution for some considerable time. Tractors replaced steam plows and mules for plowing. Tractors also replaced mules to a lesser extent for hauling cane and for various cultural operations. Cutting back was abandoned. Stripping was largely abandoned. Field work in general was speeded up and was subjected to more intensive supervision. Fertilizer practices were changed. Harvesting was altered by the introduction of loading machines. The cropping cycle was decreased. Irrigation, i. e., the actual method of applying irrigation water, has, perhaps, changed less than any other plantation operation, so far as the industry as a whole is concerned.

Sporadic and increasing signs of unrest, however, have been evident in irrigation circles for some time. About twelve years ago (as described in *Report of Committee on Cultivation, Fertilization, and Irrigation on Irrigated Plantations for 1921 and 1922)* Kilauea Sugar Plantation Company burst forth with the Modified Orchard or Long-Line system for its plant fields, and the Automatic Cut-Line or *Huli* system for the old ratoon fields.

About the same time, H. W. Baldwin, section overseer at Hamakuapoko, worked out the so-called Herring-bone system of long lines fed from flumes, and also from slip-joint pipes. This system, which in our opinion, still has merit under certain conditions, was also described in the *Report of the Committee on Cultivation, Fertilization, and Irrigation on Irrigated Plantations for 1922.*

In the years 1923 and 1924, Hawi Mill and Plantation Company made extensive installations of the Overhead Sprinkler system. This was followed by Honokaa Sugar Company on a somewhat less extensive scale, and was tried out at quite a number of other places.

In 1928, Koloa Sugar Company developed a distinct modification of the Standard Contour system, very similar to a system long used at Kekaha Sugar Company. It was accompanied by the practice of pushing back the cane in level ditches and watercourses. This system generally known as the Koloa system was grabbed rapidly and became standard on several plantations. (Described in the *Planters' Record* for October, 1928.)

In 1930, Renton and Bond described the Ewa Border or flooding system (as reported at the annual meeting of the H. S. P. A., 1930). This revolutionary system was tried on many other plantations with considerable success.

*** Presented at eleventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October, 1932.**

Early in 1931, Wailuku Sugar Company went in wholesale for Automatic Cut-Line irrigation on its ratoons, and started with long lines for plant.

The same year Waimanalo Sugar Company installed its classic replicated Level Ditch experiment with long lines vs. contour and planted a number of fields on the Long-line system throughout.

Gradually, all irrigated plantations began to doubt the infallibility and supremacy of the Standard Contour system. In less than two years' time the Standard Single-Line Contour system has practically vanished. Nearly everyone has changed over to lesser or greater modification of the Standard system, or has gone in for one or another of the various newer systems.

From it all, something useful should evolve. It is not to be expected that one standard system will ever be adopted for the whole industry again, any more than that one standard fertilizer formula can be expected. Local conditions of soil and contour will govern the methods to be used. Each plantation, type of contour and soil will be a study in itself. The supremacy and wastefulness of one standard system has been eliminated, and irrigation methods have become a more interesting and more intensive field of study for the intelligent field man.

When this subject was assigned the writer, it was decided that instead of collecting data from the various plantations, and compiling a paper on what has been and is being done on the plantations, along the line of new irrigation systems, it might be preferable to let the men who are actually doing this work describe to us what is being done.

Letters were therefore written to the various plantations and to members of this Association from the various plantations, asking that some representative or representatives from each place come to this meeting prepared to tell what has been done along the lines of irrigation, what degree of success has been attained, and what plans for future development are under way.

The newer systems, so far as they have been seen, may be classified roughly under two headings:

(1) Modification of the Standard Contour system, and

(2) New systems, entirely distinct from the contour system.

These two classes in turn are subject to numerous subdivisions which we intend to hear about from the members present. In order to make a start, and to approach some unity of nomenclature, the main systems or groups that have come to the writer's attention will be named.

Under the first class or modification of Contour system, we have:

1. The Koloa System,
2. The Two-way System or Come-and-go System,
3. The Cut-Line or *Huli* System.

Under the second group, or systems distinct from the Contour, we have:

1. The Single Long-Line System
2. The Flooding System,
3. The Overhead Sprinkler System.

Most of these systems have developed modifications and refinements, and it is possible that some other unrelated systems may be put forth. However, we shall see.

In order to keep the discussion from wandering too much, we shall try to take up the various systems and related systems separately.*

KOLOA SYSTEM

Mr. Larsen: Let us first consider and confine our discussion to the Koloa system. This system or something very similar to it has been used at Kekaha for a great many years, as has also the practice of pushing back that is generally associated with it. Koloa plantation, however, has been chiefly instrumental in recent developments in the system and in calling attention to same as a distinct labor saving method, and it has, therefore, become generally known as the Koloa system. Will Mr. Hector Moir of Koloa Sugar Company tell us about this system as they use it?

Mr. Hector Moir: The Koloa method of irrigation, which is the two-side irrigation system, is a great saving over the old one-side system of irrigation both in man days per round and gallons of water per acre per round.

Take one field, of 45.78 acres. Under the one-side system the average men per round for the 1929 crop was 71.32 as compared with 25.60 men per round in the same field for the 1930 crop, under the two-side or Koloa method. A saving of 45.72 men per round. The 1929 crop took an average of 142,377 gallons per acre per round, while the 1930 crop took an average of only 69,896 gallons per acre per round. A saving of 72,481 gallons per acre per round. There was a saving of over 92 million gallons of water in the 1930 crop over 1929 crop for this field.

With this great saving of both men and water per round the plantation was able to reduce the rate per ton of cane paid to the cultivation contractors from $1.05 per ton of cane harvested in the 1929 crop for this field to $0.85 per ton in the 1930 crop.

The average acres per man per round was increased from 1.14 acres per man to 2.02 acres per man.

In the straight-line or long-line system there is an additional saving of men and water. In another field of about the same size of long lines, it took only 10 men per round and they averaged 4.43 acres per day and only used 44,461 gallons per acre per round.

FIELD 6—45.78 ACRES

	Man Days per Round	Average Acres per Man Days	Gallons Total Water per Round	Gallons per Man Days	Gallons per Acre per Round	Inches per Acre	Rate per Ton Cane to C. C.
One-Side System..	71.32	1.14	7,456,536	104,550	142,377	5.24	$ 1.05
Koloa System....	25.60	2.02	3,132,147	122,350	69,896	2.56	0.85
Difference........	45.72 Minus	.88 Plus	4,324,389 Minus	17,800 Plus	72,481 Minus	2.68 Minus	$ 0.20 Minus

FIELD 16—44.34 ACRES

Long-Line System.	10.00	4.43	1,971,400	197,140	44,461	1.64	$ 0.60

The Koloa Sugar Company has 2,898 acres of irrigated land and of this total 265 acres are in long-line system and the rest (2,633 acres) are all in the Koloa system of irrigation. The area in long line is being increased in the very heavy black soil in the Mahaulepu section where good surface drainage is needed.

* Discussion compiled from notes taken by R. E. Doty and Ralph J. Borden, with written notes furnished by some of the speakers.

Mr. Larsen: Will Mr. Sandison tell us about the Koloa system as used at McBryde Sugar Company?

Mr. Sandison: The McBryde Sugar Company's irrigation layout is 90 per cent two-side (Koloa) and 10 per cent one-side.

Under the two-side or Koloa system we have reduced the acre inches per irrigation from about 8.1 to 6, and the acres per man day have come up from a weekly average of .8 to 1.7. The acres per man day vary greatly according to the field, from .9 acre for first water in plant cane to 4.1 in fields where an unlimited quantity of water can be used without damaging a watercourse. Our contract rates have been reduced from 25 to 30 per cent.

DATA FROM McBRYDE SUGAR COMPANY—FIELD 4C, 1930 CROP

Koloa Irrigation vs. Ordinary Irrigation

	Koloa—32.62 Acres		Ordinary Contour—49.18 Acres	
	Acre Inches per Acre	Acres per Man	Acre Inches per Acre	Acres per Man
January, 1929	5.00	2.49	6.53	1
February "	5.12	2.46	6.48	1.07
March "	5.57	1.98	8.85	1.12
April "	5.71	2.38	8.11	1.13
May "	5.60	1.85	8.69	1.07
June "	5.22	1.96	9.47	.97
July "	5.26	2.25	8.17	1.04
August "	5.20	2.00	8.39	1.02
October "	6.83	2.30	8.31	1.49
	49.51 ÷ 9	19.67 ÷ 9	73.00 ÷ 9	9.91 ÷ 9
	5.50	2.18	8.12	1.10
Yield	91.02 tons cane per acre		90.96 tons cane per acre	

With the Koloa system we have averaged 2.75 acres per man day for the 1933 crop.

A modification of the Koloa system, which uses the idea of the one cut-line or U system is being tried.

Contracts of about 10 acres per man are given out as before. When hoeing is completed, the men are taken out and put on other work.

Mr. Larsen: Mr. Kahlbaum—what is your experience with this method at Makaweli?

Mr. Kahlbaum: We have a very indefinite water supply. Our 1931 crop was all grown under the old standard contour system. Our 1933 crop was changed entirely to the Koloa system. This change has doubled the speed of irrigation with only half the number of irrigators. We have a comparison for the first nine months of this year of .74 acre per man using the old system, with 2.0 acres per man with the Koloa system. Our 18-day interval has been cut to 13 days. Contract rates which were set at 8 acres per man have been raised to 12 acres. The irrigators take care of their weeding with very little kokua. Rates have been lowered from 90 cents to 70-75 cents per ton on the 1933 crop under the Koloa system.

For the 1934 crop we have tried a modification of the Koloa system, irrigating 60 feet each way.

Sugar tonnage has increased under the Koloa system but cane tonnage has not.

Mr. Larsen: Will Mr. Danford tell us something of this system at Kekaha?

Mr. H. Danford: Kekaha Sugar Company has used this system for over 40 years on the upper lands. We call it a two-way, four-line system. The irrigator works with two portable panis. He uses koa sticks to support the panis at every fourth line. Pushing back is always practiced. In big cane one man averaged 2 to 3 acres per day. In plant cane we give one irrigation by day work. Up to the third or fourth irrigation we use the two-way, one-line-at-a-time system, then three lines are cut. The amount of water handled

depends on whether the irrigator must hoe weeds and irrigate too. *Mauka* lands may get water as often as eight-day intervals, depending on the supply. An average interval is 15 days. We have 5,860 acres under this cut line method. Over the crop period our average costs are \$62.26 per acre; 11 cents per acre per day; \$3.29 per acre month. Average man-days per acre: 13.71.

Mr. W. W. G. Moir: A difference between the Koloa and Kekaha systems lies in the fact that in the Koloa system the cane line is lower than the watercourse, and therefore has a "spillway effect." In the Kekaha system the openings to the lines are cut to the bottom, with the bottom of the cane line level with the bottom of the watercourse.

Mr. Larsen: How about this system at Lihue Plantation Company, Mr. Rice?

Mr. P. Rice: We don't like the Koloa system. We use a system like that used at Waipahu: irrigating the lines on one side of the watercourse as we go down from the level ditch, and the lines on the other side as we come back up and finish at the level ditch. We make our lines 72 feet long and on plant cane may irrigate half way from each watercourse or we may irrigate all the way. On ratoons we put a pani in the middle and irrigate to this pani.

Mr. Larsen: How about Makee Sugar Company, Mr. Sloggett?

Mr. Sloggett: We use a system somewhat like Lihue's with 72-foot lines.

Mr. Larsen: What do you do at Pioneer Mill Company, Mr. Willett?

Mr. Willett: We have no Koloa system. We use a cut-line system and with plenty of water in wet weather can do 3 to 5 acres a day by cutting several lines. With a 3-acre inch irrigation, we do one acre a day. We are trying the Waipahu system in ratoons: down and up on opposite sides of the watercourse; eliminating every other watercourse of the old system.

Mr. Larsen: Will Mr. Hoogs tell us about the Koloa system at Wailuku Sugar Company?

Mr. Hoogs: We had 150 acres in the Koloa system in the 1932 crop. Compared with the old system of previous years it increased average covered per man day from .85 to 2 acres. We had a considerable amount of washing in the watercourses except in nutgrass fields. We will change back to the old system where washing is bad.

Mr. Larsen: Mr. Broadbent, will you tell us about this system as used at Puunene?

Mr. Broadbent: We had one-third of our area under the Koloa system and two-thirds under a modified Koloa system; making a total of about 7,700 acres. We had excessive washing with the Koloa system in some places and excessive flooding. In our modified Koloa system, we put opala in the bottom of the watercourse and irrigate down one side and back up the other, similar to Waipahu. We gave 11½ to 12 acres per man on contract at 95 cents per ton. We have cut contract prices 20 to 30 cents per ton with the Koloa system. An experiment comparing the Koloa with the single-line contour system shows 1¾ acres per man day applying 3 acre inches with the Koloa system, compared with 1¼ acres per man day, applying 4¼ acre inches with the single line contour. We keep the nutgrass where we use the Koloa system.

Mr. Larsen: How about Maui Agricultural Company? Is there anybody here from that plantation?

Mr. Lyman: Speaking for Maui Agricultural Company, the Koloa system was unsuccessful and has been abandoned. They are using the standard contour method but trying out other methods where possible.

Mr. Fassoth: Maui Agricultural Company had excessive washing with the Koloa method which required lots of labor to fix up the watercourses. Their land is better adapted to a long-line system.

Mr. Larsen: What system is Waipahu using, Mr. Wolters?

Mr. Wolters: We are using a two-way contour system and have reduced rates 10 to 15 per cent.

The new two-way contour or come-and-go system is the standard practice at Oahu Sugar Company and trials of other systems are in progress. The modifications embodied in the two-way contour system as compared with the old system are as follows: The watercourses are spaced from 70 to 80 feet apart, thus omitting every other watercourse as compared with the old contour system in which lines averaged 35 feet long. Level ditches serve from 30 to 35

lines and straight ditches are placed at convenient distances so as to have level ditches less than 1,000 feet in length.

The cane is irrigated through the full length of line between watercourses until about the fifth or sixth irrigation. The 70- to 80-foot furrows are then divided in half by banks of earth, after which two sides are irrigated from each watercourse. Starting from the level ditch irrigation proceeds down one side of the watercourse and returns upward irrigating the lines on the opposite side of the watercourse and always ending at the level ditch. After the cane lies down the *kuakua* is cut at the central pani and each side of the watercourse is a so-called two-line go-and-come system.

At about the time the banks are installed in the furrows, the cane along the watercourses, level ditches, etc., is pushed back. Cane 6 to 10 feet from the watercourse is pushed first, followed by the cane nearest the watercourse. This insures a good job that lasts since the pressure from the rest of the cane in the line is not great enough to flop it back. The suckers that come up and any growth thereafter is not pushed back as this growth is not recumbent. Pushing back is done following an irrigation or heavy rain when the soil is soft and there is least danger of breaking the cane. We have had indications from fields that have been pushed back on the watercourses of improved juice quality compared with adjoining fields that were not pushed back.

Ratoon fields have been changed over to the two-way contour system by eliminating every other watercourse in ratooning, replanting with the first water the sections of lines crossing the eliminated watercourse.

The efficiency and output of a man has been increased under this modified contour system by amounts varying from 50 to 75 per cent per 10-hour day over the old contour system. The irrigation rounds have been increased with no extra amount of water and the moisture content of the soil has been improved, all due to elimination of losses of water.

A 25-acre experiment was laid out to determine the best distance between watercourses for the new system and checked against the old system using 35-foot watercourses. Distances of 60, 70 and 80 feet between watercourses were used and the 80-foot watercourses have used the least amount of water and the cane looks as well in these plots as in the plots that have used the greatest amount of water.

Mr. Larsen: How about Honolulu Plantation Company, Mr. Fassoth?

Mr. Fassoth: We have never used the Koloa system. We prefer the *hulihuli* system, i. e., go-and-come two-line system with one cut line as practiced at Waipahu. All of our old fields have cut lines.

Mr. Larsen: Mr. Menardi, have you used the Koloa system at Ewa?

Mr. Menardi: We have never used the Koloa system. We have the regular U-system and use *opala panis.* The irrigator works down the watercourse one round irrigating both sides and back up the watercourse on the next round. On plant cane, he averages 1.4 acres per man day.

Mr. Larsen: What is the experience at Waianae?

Mr. Eremeef: Thirty acres were put in with the Koloa system. We found that it washed out our watercourses badly and we have changed to the Waipahu system.

Mr. Larsen: Mr. Butchard, how about this system at Waialua?

Mr. Butchard: The Koloa system washed badly except in nutgrass fields. We are working away from the Koloa system toward a long line and a contour border system. We are using a cut-line system in old ratoons.

Mr. Maze: Has anybody tried tamping to stop this washing?

Mr. Fassoth: We tried some tamping of watercourses in plant fields.

Mr. W. W. G. Moir: Koloa has used lime bags, and tried bitumal, which is, however, too expensive.

Mr. Larsen: What is your experience at Kahuku, Mr. Fisher?

Mr. Fisher: We have 70 per cent of our area in the Koloa system and 30 per cent in long lines. We found excessive wash on the *palis* and put in trash *panis* to check it. On some *palis,* we must change the watercourse on every other crop. This is expensive. We are trying out the Waialua system now. The Koloa system is O. K. in the lower fields. One ditchman handles 120 acres instead of 60 under the old contour system. One man now

handles 15 to 20 acres against 10 or 12 acres formerly. Our biggest saving is a 25 per cent reduction in rates. On the high fields a man is covering 2 to 2½ acres a day; on the low fields he makes 7 to 10 acres.

Mr. McCall: Has pushing back at Waipahu affected the juices?

Mr. Wolters: Pushing back has not damaged the juices at all; in fact we have definite evidence that the juice is better under the Koloa system. The suckers along the watercourse have a better chance to mature.

Mr. Willett: At what age does Waipahu push back?

Mr. Wolters: We push back at 4 to 6 months, after about the sixth or seventh irrigation.

CUT-LINE OR *HULI* SYSTEM

Mr. Larsen: Let us now consider some of the cut-line systems. Various cut-line systems have been used for years—often by the contractors without the knowledge of the plantation management. Two- and four-line cutting has been up for discussion on numerous occasions. Cutting the entire level ditch has also been practiced locally and spasmodically on several places. Pioneer practiced a cut-line system in their steeper fields for many years for the purpose of handling freshet water. They ran some experiments on this which may be of interest at this time.

Kekaha Sugar Company has also practiced cut-line irrigation as a standard practice in some fields for many years.

The automatic cut-line system is a modification of these earlier cut-line systems, designed to automatically control the water entering the lines, and to enable more area being handled per man per day. It originally involved the use of pipes or gates of some sort, but in many cases these have been omitted. Its use on a large scale with pipes was started at Kilauea in 1922 and was continued there until contour irrigation had been entirely replaced by long-lines.

Wailuku went into cut-line as a standard system early in 1931 and since then has put all its ratoon fields into this system in one form or another.

Honolulu Plantation improved the Wailuku system by the use of iron panis and certain other modifications.

The no-water course cut-line system was started as a distinct system at Paauhau in 1931, after which it spread to Kohala where it underwent some drastic changes and then was adopted at Wailuku as the short-line huli system.

Mr. Hoogs, will you tell us about the cut-line system at Wailuku?

Mr. Hoogs: We changed 2,500 acres to the long-line (35 feet) *huli.* For the 1934 crop we have gone into the short lines (17 feet) *huli,* using *pani.* We need twice as many level ditches, with 15 lines per level ditch instead of 30, but have no watercourses in the new system. We get better irrigation. Last year the installation costs on the long-line *huli* were very high because we had to move so much *lepo;* now they are cheaper on the short-line *huli.* We had to enlarge our ditches. The old watercourses were planted up. In plant fields on the *palis* we use pipes from the level ditches. One man can take care of about 20 openings on one ditch. We prefer the distribution of water in two ditches instead of in one. Fields have been carried through for 40 days against 20 days under the older system. The grade of level ditch is .3 per cent. We use no gates; stakes are driven into the ditch and an *opala pani* used.

Mr. Larsen: Perhaps Mr. Bond will tell us about the short-line *huli* used in Kohala?

Mr. K. Bond: The system offers a rapid method of distribution. On steep grades a large stream of water is divided into smaller streams for distribution and short 15-foot lines in the *huli* system are used. This *huli* system is not applicable to flat lands. Longer lines are used elsewhere. We pay 30 to 35 cents per acre against $1.00 per acre under the old contour system. The number of acres per man on plant fields is not set. We give 30 acres per man on long term contract.

LONG-LINE SYSTEM

Mr. Larsen: Since our time is very limited it will be necessary to dispense with further discussion here and consider some of the methods other than contour, such as long-line and border systems.

Years ago, before the standard contour system was developed, irrigation in the Islands consisted of running the water more or less with the slope whether in the cane row or between the cane rows. In Australia the same system was being used in 1929 when I visited there.

The present long-line system uses the same principle with the exception that a level ditch is now used, out of which pipes, gates, or cuts lead the water from the ditch into the cane row—in an attempt to start as many lines as possible at a time. The main difference in the new system is that a large stream of water is used in large supply ditches or level ditches, which enables the irrigator to run a great many lines at one time. Numerous variations have come into effect, of which we expect to hear from you. The original description in 1931 tells of the first field laid out to the so-called Modified Orchard system at Kilauea, and reports 28 acres irrigated per man day, under a most favorable layout. The following year in 1932 a full report is again given in which certain modifications have begun to appear. The principal modification is a deeper line with water running in the cane row, rather than between the cane rows, and contouring along the steeper hillsides.

We should like to hear from a Kilauea representative as to what modification in the system has taken place since that time with them, and what they are doing at present in the way of acres irrigated per man day, water consumption, or any other data they may have to present.

Mr. McCall, will you tell us something of the Kilauea Long-line system?

Mr. McCall: We formerly used a straight line but now it is more of a continuous line which is not too steep but sort of follows a contour. The spacing between lines is 4½ feet. It has been adopted for a cultivation practice in which a furrow opening is made close to the cane. Fertilizer is put in this furrow. We use a sliding (Makee) furrow opener on a cultivator to open this water line and also to cover seed in a plant field. The water line is put on the upper side of the cane row. We have recently used a Stubenberg opener to open this furrow. Over an average of 1600 acres we can irrigate 7½ acres per man day (all fields). In plant fields we do 1½ to 2 acres per man day. For later irrigations, 17 to 18 acres per man day is obtained on favorable land. We cultivate between every irrigation for weed control. Our water consumption is from 2½ to 4.84 acre inches per acre per irrigation, and as low as one acre inch.

Mr. Danford: Kekaha uses a straight line irrigation in the swamp lands where irrigation serves a double purpose of washing out the salt and watering the cane. Our lines run from 100 to 200 feet long. The average man days per acre over the entire crop period is 6.71; the average cost per acre month is $1.66. We have 1740 acres in long-line irrigation.

Mr. Wolters: We have 300 acres on the peninsula coral soils in long line and 60 acres up mauka. Lines are about 200 to 250 feet long and have a fall of ½ to 1½ per cent. Lines should be shorter for slopes less than ½ per cent. We keep the water *in* the cane row. The men cover 2½ times the area with less water than the old system.

Mr. Sandison: At McBryde, we have no long-line irrigation owing to the compactness of our soil preventing an even distribution or the application of an adequate amount. Long-line contour has no advantages for us over a two-side system.

Mr. Fassoth: At Hawaiian Commercial and Sugar Company on the tight red soils we note a low penetration of water with the long-line system. With a slope of 1½ per cent there would be poor cane about three-fourths of the way down the grade. So we put trash panis in the lines to back or slow up the water.

Mr. Menardi: Ewa had the same experience in their borders. We must use trash to slow up the water on a tight soil.

Mr. Willett: Pioneer had the same difficulty of dry spots everywhere in borders on grades of 1 to 1½ per cent.

Mr. Wolters: The length of line must be proportionate to the fall and soil type.

Mr. Larsen: Will Mr. Beveridge tell us of Waimanalo's experiment with long line versus contour?

Mr. Beveridge: In our experiment we gave 17 irrigations with both methods. We have no cost data but have figures as follows:

Method	No. of Level Ditches	Total Acre Inches Applied	Acre Inches per Irrigation per Round	T. S. A.
Long line	6	37.36	2.2	7.01
Contour	6	37.11	2.1	6.41

We have lower costs with the long-line systems and have harvested two plant fields with good results. We have planted some 800 acres to this system during the past year.

Mr. Larsen: In this experiment mentioned by Mr. Beveridge every alternate level ditch for the entire length of the field, was laid out to long lines and every other one to standard contour. The water applied was measured at each ditch. It is noteworthy in the harvesting results that in every case the long line level distinctly outyielded the adjoining contour levels in both cane and sugar.

Mr. Broadbent: Is inadequate moisture at the end of the long line common?

Mr. Larsen: That would depend on the type of soil, the contour, etc.

Dr. Mangelsdorf: Does the upper line in the *huli* system grow better?

Mr. K. Bond: We have not noticed any such difference.

Mr. Denison: Is there any washing in the *huli* system?

Mr. Hoogs: Yes, on the steeper slopes we must use *opala*.

Mr. Larsen: How about installation costs?

Mr. Fassoth: With the long-line system it costs us $3.50 an acre from furrowing to the first irrigation.

Mr. Hoogs: Some comparative Wailuku costs are as follows:

Long-line *huli* planted at $23.00 per acre with 15.3 men per acre (35 feet).
Short-line *huli* planted at $11.00 per acre with 3¼ men per acre (15 feet).
Border system planted at $22.00 per acre with 9 men per acre.
Long-line system planted at $6.58 per acre with 1¾ men per acre.

There is very little *huki lepo* with the short-line *huli*.

Mr. Burnett: Has anyone a satisfactory cultivator for the long-line system?

Mr. Alexander: The light V cultivator used at Kilauea does good work.

Mr. Larsen: Kilauea at present plants flat instead of deep, and starts cultivating right away with ordinary riding and tractor cultivators. When they planted deep in the furrow the "V" cultivator of which Mr. Alexander speaks, was developed and worked very satisfactorily.

FLOODING OR BORDER SYSTEM

Mr. Larsen: We will now consider the Ewa Border system before our time is up. This system was described very thoroughly in a report by Mr. Renton and Mr. Bond in 1930. Since then certain modifications have taken place, chief of which, I believe, is the Aiea Contour Border or Terrace system.

I shall call on the Ewa representative to tell us of further progress, developments, and results since their last report. Mr. Menardi.

Mr. Menardi: We have now had 4 years experience with the border system. We have taken off 5 experiments comparing contour versus border, and have harvested an average of 120.48 tons cane with 14.93 tons sugar from the border against 120.25 tons cane with 14.87 tons sugar from the contour. Two experiments showed the border better than the contour, with significant T. C. A. gains of 3.8 and 6.0 tons, one showed a significant gain of .58 ton and another a significant loss of 1.03 tons for the border. This loss was due to treatment

rather than the system because the border received less water. The border system did not average 4 acre inches per irrigation. This year we are using a double irrigation practice during the "boom stage"; one irrigation of 2 acre inches followed the next day by an irrigation of one acre inch or more. We aim to supply 4 acre inches or more. A small stream on a steep slope does not give an even distribution from side to side of border. Therefore a double irrigation is preferred. The border method uses 7½ to 8 man days per acre per crop.

Mr. Broadbent: In our experiment, we had to give twice the number of rounds in the border as in the contour, because the cane in the border system did not get enough water with the same interval as the contour.

Mr. Menardi: In our experiments, the greatest slope was about 4 per cent. We have used slopes up to 7 per cent in spots but we do not advise such steep grades.

Regarding our weed control in the border system, our costs were too high. This year we have tried different methods of weed control, keeping data on costs and man days required. For fields now closed in the average total cost is $6.62 per acre for the Ewa border system and it has required 5.38 man days. We feel that it will not take over 6 man days or $7.50 per acre with the Ewa border. We are getting away from giving out contracts on plant fields. For irrigation only, for all conditions over an average of 17 months, we average 9.06 acres with the border against 1.47 acres with the contour. With the contour method we need 25 to 30 man days to bring a crop to maturity, as compared with 5 to 6 days with the border, but we must add 6 to 7 man days for weeding. Thus we need less than 15 man days to bring a crop to maturity with the Ewa border.

Contracts are now being given out by blocks rather than by fields. This concentration of water will help to save some of the 13.9 per cent more water that the scattered areas in the border system required previously. We now have 2500 acres in the Ewa border. It has not increased the use of water for the plantation as a whole. In 1927, we were using 10 acre inches per acre per irrigation whereas now we use 7½ to 8 acre inches.

Mr. Broadbent: The average depth of irrigation over the whole plantation has been cut down with the border system. We pay 35 cents per ton for irrigating and weeding.

Mr. Sandison: We have considered some of the newer methods, such as border, contour border, long-line contour, straight line, and a 15-foot-line *hulihuli* system which Mr. Shaw described to us a few months ago, but we are not adopting any of them in the meantime for the following reasons:

1. The topography of our land renders the installation of ordinary border irrigation impossible.

2. We have two acres of contour border and again chiefly for topographical reasons no further installations will be made. We feel that land suitable for contour border should not have a natural slope of more than 4 per cent, while most of our land varies from 6 to 20 per cent. Even at 4 per cent, borders can only be 10 feet apart, and they require nearly the whole of the first foot of soil to make them durable.

Mr. Larsen: I am sorry to note that our extended time limit has expired and it is necessary to end the discussion. I know there are several more representatives present with interesting data on long line, Ewa Border, and Aiea Terrace systems, that we should like to hear, but these will have to wait for another time. By next year there should be more specific cost data available from completed fields, that will show the entire picture of men days and costs at maturity. It should always be borne in mind that irrigation is only part of the picture, and that in looking at any new system the entire cost of growing the cane must be considered. Cost at maturity or men days at maturity is the proper comparison to use from a performance angle.

We have heard references made to drastic cuts in contract rates under one system or another. This also does not show the entire picture. The question at once arises as to how much additional work is done outside the contract and how much of the cut is due to current reductions in general wage rates or expected earnings. Due to increasing yields and a general failure to reduce cultivation contract rates accordingly, long term contractors have in recent years been paid on a more generous scale than other types of field workers. During the wage curtailment program that has taken place during the past year it is noted that this

rather evident discrepancy has been readjusted. In studying the effect of new systems on contract rates and total costs, this general reduction must be borne in mind. A better unit for measuring performance, therefore, is men days per acre or per ton cane for irrigating and weeding combined, or of total men days at maturity. This would give us a truer picture of comparative performance of two systems than can be had from contract rates or even cost at maturity.

Sunlight Hours in Hawaii

Condensed from a Technical Paper by A. H. Cornelison

Is it the amount or the quality of sunlight which has a definite effect on the yield of a Hawaiian sugar plantation? Should not the angle at which the land is exposed to the sun's rays be considered as one of the constant factors which may influence production?

In an effort to stimulate interest in the effect of sunlight in Hawaii a beginning has been made in arriving at the mathematical relative value of an hour of sunlight for summer and winter months on lands of various slopes. The study was made from the point of view of the angle at which the sun's rays strike the earth at these two seasons, disregarding, due to lack of knowledge concerning them, the effects of absorption and reflection on light coming through the earth's atmosphere.

The study is based on the fact that, in the earth's rotation in a slightly elliptic orbit about the sun each year, its axis is never perpendicular to the plane of its orbit. In the northern hemisphere this causes an apparent tipping toward and from the sun in the summer and winter months, respectively. In winter the earth is tipped away from the sun in the north and toward it in the south, while the reverse holds true in the summer. The tipping causes the seasonal variation in temperature and light intensity.

The summer months are warmer in Hawaii because more of the earth's area located on the north side of the equator is exposed to the more vertically falling rays than is true for the opposite hemisphere at the same time: thus more area is getting greater amounts of energy in one case than in the other. In addition, as the earth rotates its varying faces toward the sun, the total time that an area is exposed to the light changes greatly. The mass of the earth at the equator interposes itself and cuts off part of the light that would normally go to the area tipped away from the sun, whereas that tipped toward the sun gets more light, thereby, on its side of the equator. This accounts for the difference in length of day between winter and summer.

An impression may prevail that, though it is colder in winter than in summer, the sunlight would be almost as intense during both seasons were the air not a factor in cooling the area off. This is extremely in error for winter sun is 30 per cent less effective than summer sun so far as energy per unit area of flat land is concerned in Hawaii.

In earlier studies which considered the total sunlight hours alone the fact was disregarded that it is the length of daylight multiplied by its relative intensity that gives us the relative energy received. Thus, while the hours of daylight are longest on June 21, the total energy received is slightly less on this date than it is on June 1 or July 9 because the intensity of the light is higher then than it is on the longest day when the sun is in a more inclined position to the north. For all purposes the hours of daylight from June 1 to July 20 are almost equal

in value for flat land and it is of interest that June 21 is theoretically somewhat less in effectiveness than any other day of the month.

Except for local rainfall conditions, cooler temperatures and possible resulting cloudiness, plantations on steep south slopes will have the effective sunlight periodicity of land lying much closer to the equator and will be subjected to less seasonal variation in temperature and energy received than a plantation on level land in the same latitude.

Plantations on north slopes of more than 3 degrees can never hope to receive full theoretical intensity of sunlight as the sun never reaches a perpendicular above it and also because the declination of the sun behind the interposed land mass makes the hours of daylight shorter, especially during mid-winter months. In this, a third factor is also effective for most north slopes in Hawaii cause condensation of cloud masses that pile up to considerable heights above the land, obscuring the sun through additional degrees of its possible exposure.

Sun spots occurring in 11.1 year cycles are also causes of differences in wave lengths, intensity, electro magnetic disturbance, etc., and the Smithsonian Institute is attempting to determine their values. The variation is not pronounced and is not predictable at present.

Little is known concerning the use of sunlight energy in the life processes of the cane plant. It is generally understood by plant physiologists that several bands of light in the violet and ultra-violet and several in the red and infra-red rays are used. It is believed that most of the bands in the yellow and green are not used, thus causing the green color we commonly associate with plants due to their non-absorption of those rays. The bands in the violet end of the spectrum are very high in energy and are generally considered to be the ones used by the plant in the breaking down of inorganic chemical compounds in the leaf and the building up of extremely complex organic compounds such as sugars, proteins and fats. The effect of the red rays is not definitely known, but they are now being studied by the Smithsonian and Boyce Thompson institutes.

It is also known that when sunlight passes through different thicknesses of vapors, gases and dusts these materials absorb, filter out and in some cases reflect certain colors of light in such ways that the surface of the earth receives only a part of the original rays which enter its atmosphere. These effects are also being studied by the scientific institutions.

It is to be hoped that it will be possible in the future to make a study of the absorption of light by the cane plant and its effects on growth and sugar formation measured in a quantitative way.

It is highly regrettable that at present so little is known of the most important of all of the supporters of life, the sun.

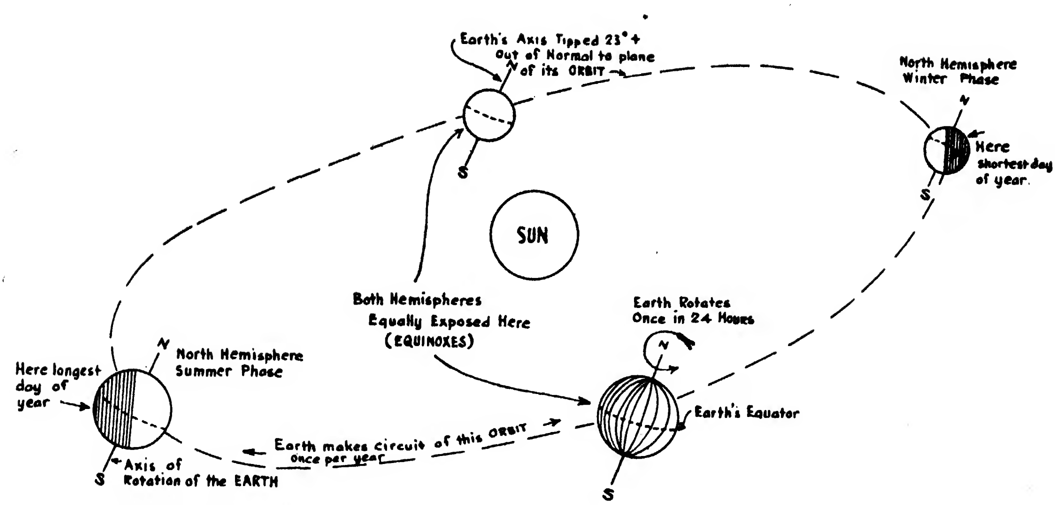


Fig. 1. The four seasonal positions of the sun and earth.

During the earth's rotation in a slightly elliptical orbit about the sun each year, its axis of rotation is never perpendicular to the plane of its orbit. This causes an apparent tipping toward and from the sun in the summ r and winter months, respectively, in the Northern Hemisphere.

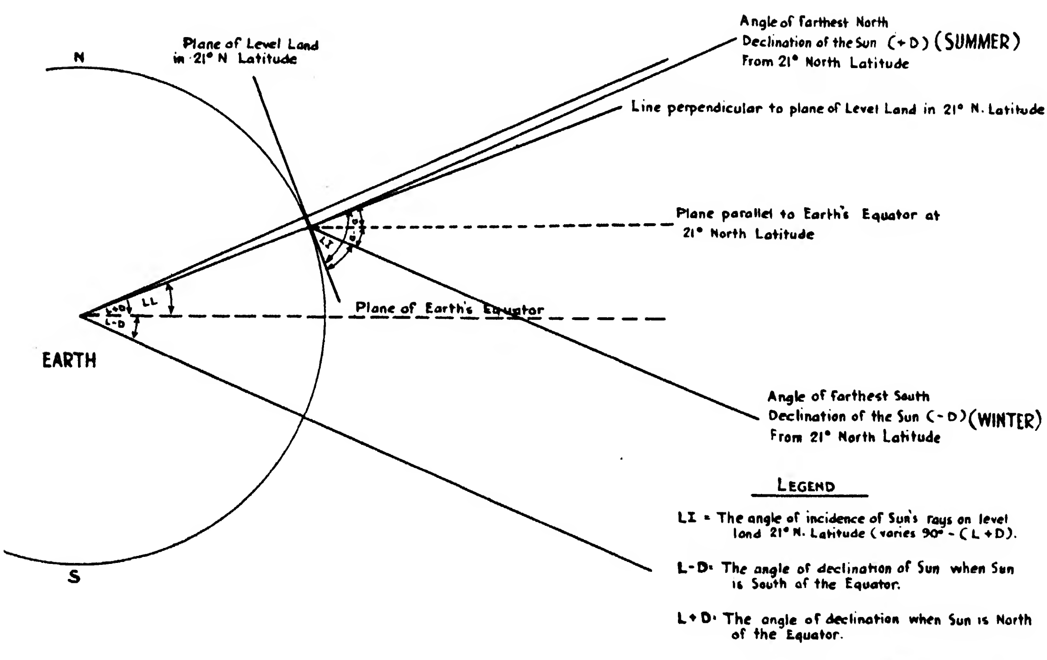
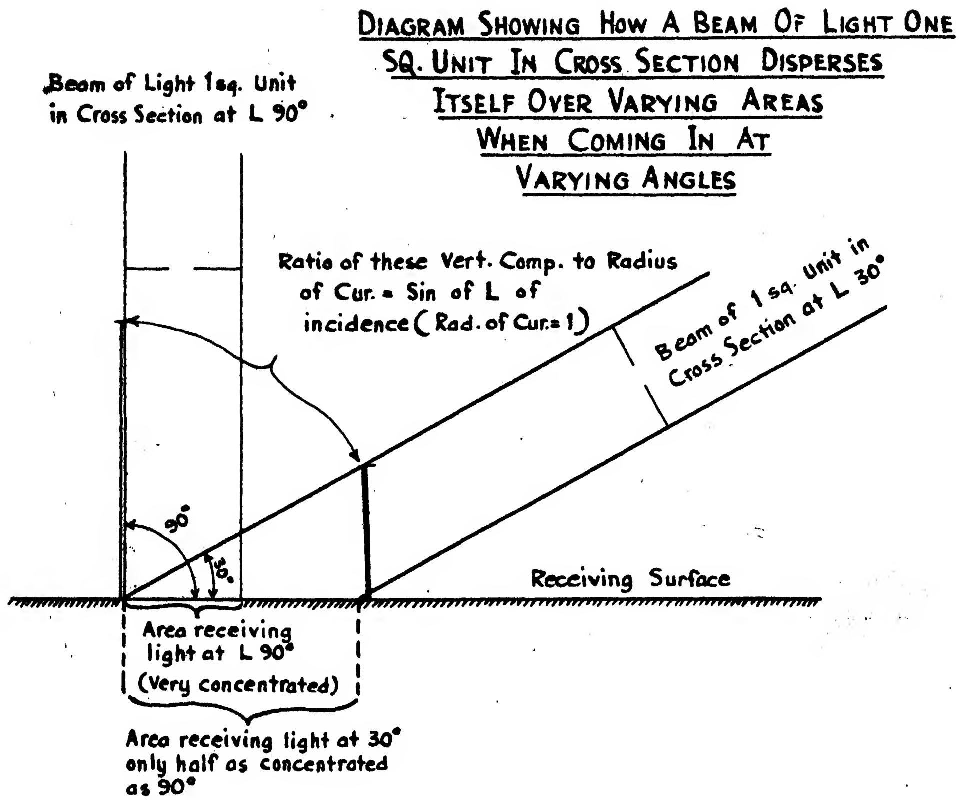


Fig. 2. Relative positions and angles of sunlight on the earth.

The Hawaiian Islands, at an approximate latitude of 21° N., receive the maximum intensity of radiation in midsummer, while during the greater portion of the year the sun is angularly coming in at less than perpendicular. The angular difference from one extreme of declination to the other is, approximately, 46°.



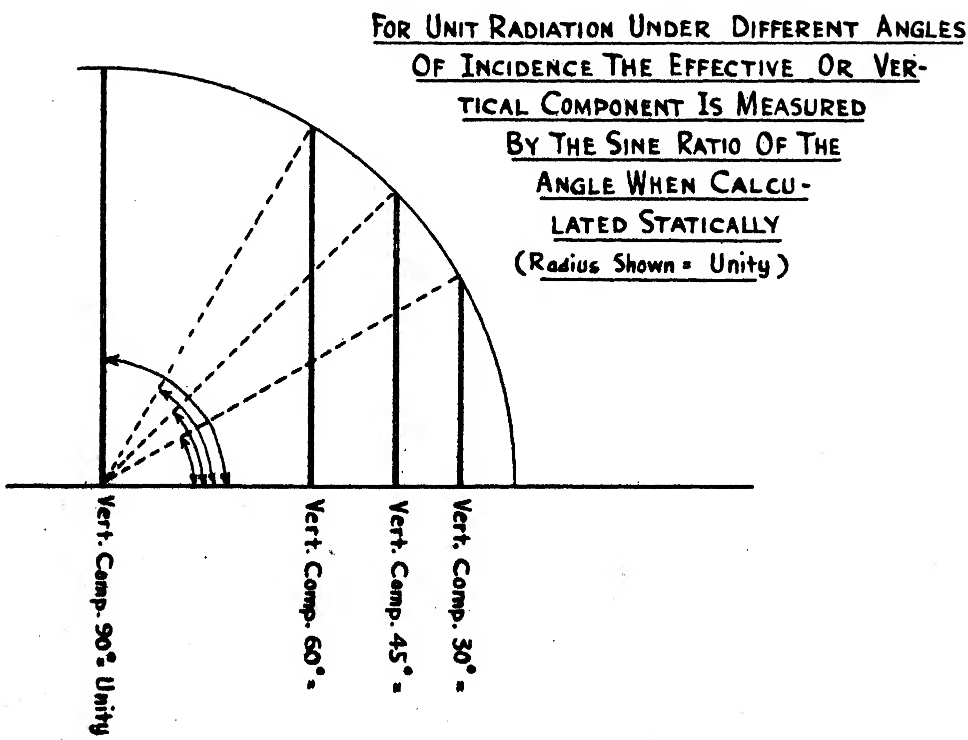


Fig. 8. For any given beam, the maximum intensity of radiation received will occur as the beam becomes normal to the plane of the receiving surface.

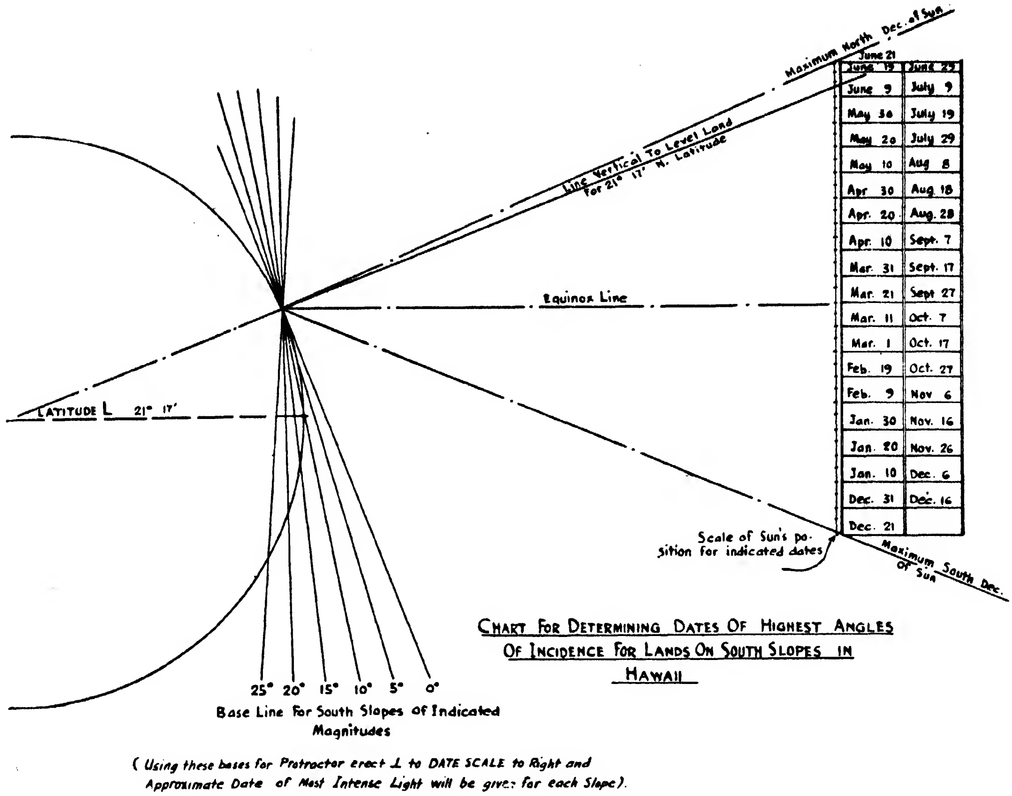


Fig. 4. With the exception of local rainfall conditions, cooler temperatures and possible resulting cloudiness, plantations on steep southern slopes will have the effective sunlight periodicity of land lying much closer to the Equator and will be subjected to less seasonal variation in temperature and energy received than a plantation on level land in the same latitude.

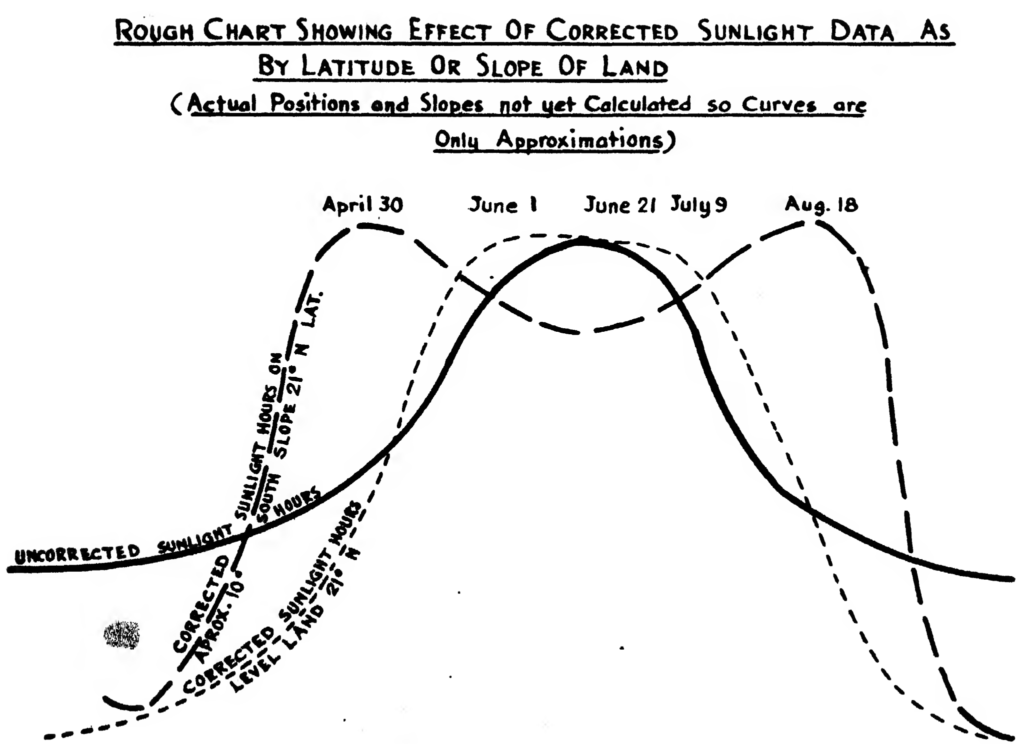


Fig. 5. The closer the land affected lies to the tropics of Cancer and Capricorn, the closer together do the two peaks of sunlight intensity fall in the curve; while the closer to the Equator the land lies, the farther the peaks separate.

Beri-beri *

A report from the Customs Department shows that 86,687,461 pounds of clean rice and 763,769 pounds of brown rice are imported annually to the Territory. According to local statistics 4,557,905 pounds of clean rice are produced annually in the Territory. This brings the consumption of clean rice up to 91,925,506 pounds, or a per capita consumption (men, women, children and infants) of 249 pounds. Besides this the Oriental population consumes 87% of the white bread produced. It is hard to conceive of a population consuming such amounts not being definitely vitamin B deficient and definitely acid residue in excess. These are real dietary faults that the future health of our community demand that we give careful consideration.

In a study of the diet of 100 Japanese families in Honolulu in 1929, it was found that a family of six, two adults and four children, used on an average 100 pounds of rice per month. On one of the large plantations of the island the consumption of rice by the Japanese laborers was higher—about 120 pounds per month by a family of six. On the same plantation the Filipinos were found to use still more. A family of four, two adults and two children, used on an average 130 pounds per month.

During that year (1929) 170 babies were born on one plantation, and 29, one year of age or under, died. This is a death rate of 172 per thousand. (The rate for Caucasians last year was 29 per thousand.) Six between one and two years of age also died. Death certificates show that 14 died of pneumonia and eight of beri-beri. In addition to the eight who died of beri-beri, there were 13 others born in this year whose mothers had a history of having had beri-beri. All of the latter were Filipinos. No data on Japanese and other races are available. However, it is very likely that our high death rate from pneumonia is due to the poor condition of the infants resulting from vitamin deficiency.

The dietaries of the families studied in Honolulu and on the plantation are believed to be representative of those of the laboring class of the Territory as a whole. The consumption of 40-50 pounds of rice per month by individuals weighing from 100 to 130 pounds seems enormous, yet 50 pounds per month is not an unusual amount for a plantation laborer. This furnishes on an average 2675 calories per day, which according to Van Noorden's estimate would satisfy the daily caloric requirements of an individual weighing 110 pounds at hard muscular labor. Certainly this amount of rice precludes the consumption of much other food and of course leaves the mechanism functioning with a dietary imbalance. It has been long known that an excess of polished rice in the diet may result in beri-beri. In the Philippines, some doctors believe that a person who eats a pound or more of rice a day can develop beri-beri regardless of what else he claims to eat.

Detailed studies of home conditions, dietaries, and histories of illness of the various members of the families lead to the conclusion that beri-beri is much

* **Taken from The Queen's Hospital Bulletin, Vol. VIII, Nos. 5-6.**

more common in Hawaii than it appears to be from vital statistics. The disease, in acute form, in adults is easy to diagnose. However, many must be stumbling along close to the verge of acute beri-beri symptoms. One doctor reported a large number of Filipinos coming down with acute beri-beri during a hundred mile hike. They had all started out apparently in fit condition. In infants the symptoms are often not marked, and are not recognized. Frequently there is no history of illness other than a recent loss of appetite with cyanosis or convulsions a few minutes, or perhaps hours, before death. In such cases, if an autopsy is performed, it usually reveals a well nourished infant with no gross pathology. There may be a few suspicious spots in the lungs or a nasal discharge. A diagnosis has to be put on the death certificate, so the baby is "signed out" as a victim of respiratory disease, usually broncho-pneumonia. An investigation of the mother and home is sometimes most illuminating.

The following case was actually investigated and is typical of many. The whole family was under par. The mother had pain in her joints and moved about with difficulty. There was some edema, especially at the ankles, with deep pitting on pressure. Her knee reflexes were not quite normal. Questioned about her diet she said that she did not like milk and vegetables. She ate "plenty" of rice —as much as 40 pounds a month. The baby was breast fed and had never been sick a day until the present illness. He lost his appetite for a day or two and became listless. He did not have any cough, just a little cold with no fever—at least he did not feel hot. Suddenly he turned very pale and gasped. Before a doctor could be found he was dead. This story has been repeated over and over again. Was the malady beri-beri or pneumonia?

Sometimes the baby loses his appetite, becomes listless and may even have a convulsion, but he does not die. The mother decides that her milk does not agree with the baby and gives him a formula. There is almost immediate improvement. The mother feels better too. The next year there is another baby. He looks all right when he is born, but within three days he is dead of "malnutrition."

However, with the large number of dramatic cases as well as deaths known, there must be a greater number who are deficient and on the verge of symptoms. What effect does this inefficient but not incapacitating condition have upon the working effectiveness of a large percentage of the population?

Some doctors who have watched this problem for a number of years have believed that the great vitamin deficiency problem in Hawaii is a lack of vitamin B rather than D. Vitamin D is highly advertised on the mainland and stressed in the scientific literature. It is important in places, but hardly in Hawaii, where 7½ hours of sunshine is enjoyed the year around. (Based on statistics of 20 years.) Dietary studies made thruout Honolulu and rural Oahu, by the Research Department of The Queen's Hospital verify these opinions and indicate the greatest vitamin deficiency in the diet of the laboring class is vitamin B.

Beri-beri is one of the simplest of all diseases to prevent and cure. It has long been known that it never occurs when brown rice, potatoes or poi constitute the chief carbohydrate food. It can be cured and prevented simply by the addition of the polishings of brown rice to the diet. The active principle in the rice polishings which prevents beri-beri is called vitamin B or water soluble B because

of its easy solution in cold water. It was the first vitamin to be discovered. Vitamin B is now known to be a "complex" containing other vitamins as well as the anti-beri-beri one. It is found in fruits and vegetables, milk, whole grains, beans, potatoes and yeast. It is more stable at high temperatures in acid than in alkaline solutions and is not destroyed by ordinary cooking. Among the richest sources are rice polishings, yeast, beans (kidney, navy and soy), asparagus, raw spinach and tomatoes. Proprietary extracts of wheat germ and rice polishings containing vitamin B in various concentrations are used medicinally.

It is well recognized that a deficiency in the diet of any of the essential food constituents results in a deranged metabolism which increases the liability of the individual to various ills. The vitamin B complex has been extensively studied and it is generally agreed that fatigue, lack of muscle tone, loss of appetite and gastric atony are part of the syndrome resulting from a deficiency of this food factor. With the vast amount of information at hand and the means of prevention and cure so easily available, why is it then that beri-beri should be so common in Hawaii?

An infant health center was started as part of our present research project in February, 1930, in an isolated Filipino village on one of our plantations. Two months of intensive effort resulted in the enrollment of a single baby in April, 1930, and much first-hand information in regard to the psychology, living and food habits of the people. With the enthusiastic cooperation of the plantation management, and hospital staff, the health center has grown phenominally in size and influence in the community. There are now two centers, one for the Filipinos and the other for the Japanese, with an enrollment of 110 babies at the present time and a daily attendance of more than 90%.

The total number of babies enrolled during the period of 18 months is 133. Some of these have been discharged because they have reached the age limit (2 years), and others have left the plantation. This large number of babies under daily observation and constant supervision affords a rare opportunity for dietary and clinical studies.

The entire number of babies enrolled is divided into groups, each group receiving specific treatment. Each new addition is assigned to the group that seems best suited to his needs. Milk formulas are prepared according to requirements, every baby having at least one supplementary feeding a day and vegetables, poi, etc., are added according to an age schedule. In addition, certain proprietary vitamin preparations, cod liver oil, yeast and water extract of rice polish are used in certain groups. Control groups are had from those families who do not patronize the health center. Every new born Filipino baby is regarded as a borderline beri-beri case and is given vitamin B in some form on the day of birth, or soon after. One day's delay in beginning treatment, has recently meant the death of two babies under our observation, but not our care.

The necessity of prompt treatment is recognized by many of the parents. Recently a father was at the door of the Health Center at 7:30 a. m. waiting for it to open so that he could register his new son who had arrived at 5 that morning and to get his "kaukau." By 9 a. m. the baby had had his first dose of vitamin

B. This baby is living and thriving—the second survivor of 7 children born to these parents.

As a source of vitamin B a cooked water suspension of baker's yeast has been used in one of our groups. Yeast has also been given to certain expectant mothers who had a history of having had beri-beri. Through the courtesy of the Standard Brands, Inc., an unlimited supply of Fleishmann's yeast has been available for the mothers and babies in this group. In several cases where the prognosis was exceedingly grave, we feel that yeast therapy saved the babies' lives. Of more than 25 babies receiving the treatment, no digestive upset or diarrhea has occurred. During the 18 months the Health Center has been in operation, no baby enrolled has died. Many on admission have been regarded as exceedingly poor risks. No case of clinical beri-beri has developed, nor has any serious case of pneumonia, bronchitis or diarrhea occurred. This may sound like a patent medicine advertisement; however, it is not presented as a cure-all but merely to call attention to the need of more vitamin B on our plantations. Again we wish to emphasize the fact that, important as saving the babies might be, the number who actually die are much less important than the large number who just barely pull thru and become inefficient physical and mental citizens. This is the great load that the Territory must be relieved of.

Growth curves of the Japanese and Filipino babies show that at birth the majority are just as large as the average new born white child. Seven and eight pound babies are common. Until they reach the sixth or seventh month their growth curves closely approximate that of the standard for the American baby, then they begin to plateau and lag and never regain the same growth rate. Experiments on litters of white rats conducted in the Health Center as a demonstration for mothers show identically the same kind of curves, those on a milk, meat-vegetable puree and poi diet, grow rapidly and develop into vigorous animals. Their litter mates of the same size at the time of weaning and subsequently fed on rice and salt cabbage (the principal foods of the Japanese) are permanently stunted in growth.

Babies entering the Health Center after 6 months of age are usually difficult to feed. Their appetites are poor. In many plantation babies of this age, muscle tone is exceedingly poor. It may be, that as in the animal experiments of Cowgill and associates, vitamin B deficiency in the mother's milk has resulted in loss of muscle tone. On the other hand, a number of babies, whose expectancy of life at birth was exceedingly doubtful, have developed amazingly well on mother's milk with a supplementary feeding of cow's milk and vitamin B. Maintenance of the growth rate comparable to that of the American standard for the white child appears to be purely a matter of food, for the first two years at least.

As far as vitamin B is concerned there appears to be no good reason why any person should suffer a deficiency of this food factor in Hawaii and yet facts brought out in this investigation supported by clinical observation, leave no doubt in our minds that a very large per cent of the laboring class is suffering from a deficiency more or less of so-called water soluble B vitamin.

At the conclusion of the survey made on the pre-school children in 1929 an effort was made by us to introduce bread containing rice polish as part of the mid-

morning luncheon in one of the kindergartens, but this was unsuccessful. The United States Department of Agriculture through the Bureau of Home Economics has advocated the inclusion of rice polish in bread and has worked out recipes for it.

From time to time during the past year effort has been made to introduce rice polish into the diet of the plantation laborer, but with little success. A few beri-beri cases have eaten it plain and in every case recovery has been rapid. Mothers have been instructed how to make a mush out of corn meal and rice polish, but this also is not looked upon with favor. A mush of rice polish has also been used at the Queen's Hospital for the treatment of cases.

The present method gives promise of greater success, that is, the addition of the water soluble extract to milk formulas and to the babies' foods prepared in the Health Center, kindergarten and school. A large group of babies and children are at present receiving in this way what is regarded as adequate amounts of this food factor. The potency of the water soluble extract can be determined by animal experiments. It varies with the composition of the rice polishings, there being three layers removed from the rice grain, the middle one of these containing the greatest percentage of the water soluble vitamin. The ease with which the extract is prepared, its palatability and lack of color permit its addition to almost any food that is prepared with water. A further advantage is that it is not destroyed by ordinary cooking.

Finally it is cheap (2 cents a pound at the mill), financially within the reach of the masses.

Progress of the study will be reported from time to time.

If any of the doctors on the plantations have any further evidence or ideas from their experiences with plantation babies, the writer would appreciate hearing from them. How has this problem been handled and what is the minimum which you demand to make the diagnosis of beri-beri either on an adult, an infant, or at post mortem? We would appreciate very much any communications regarding this subject (whether you agree or disagree with the present report).

[D. A. C.]

The Composition of a Cane Crop

By U. K. Das

The sugar cane crop is complex in its composition. At harvest, a crop generally consists of cane of different age levels and probably at different stages of vigor and maturity. Thus in a plant field we may start with one shoot germinated from an eye. This stalk later gives rise to one or more daughter stalks and these latter may produce granddaughter stalks, and so on. The field is harvested, say, at 24 months of age. But how old are the daughter stalks or the granddaughter stalks? What percentage of the total yield can be attributed to these later stalks? What contribution does each of these make to the average juice quality of the whole crop?

For a clearer understanding of the how and why of the final yields, for a true appreciation of the essential factors in crop production, we must begin with a knowledge of the composition of a cane crop and its bearing on the final yield.

With these views in mind, an experiment was installed in the spring of 1931 at the Experiment Station, H. S. P. A., in Honolulu. At this time of writing the experiment has run through approximately 20 months and though it has another 16 months to go, the results obtained to date are thought to be of sufficient interest to warrant their presentation in the form of a progress report. In the following pages, some of the points of more practical interest only are dealt with. A thorough treatment of the numerous and varied data is reserved for the final report.

Layout of the Experiment

The experimental area consists of eight plots, each containing 10 lines, each line being 35 feet by 5 feet. The plots are separated from each other by a path 2½ feet wide. Four plots as shown in Fig. 1 were planted on March 17, 1931, and the other four plots on September 17, 1931. In the first case, the cane started with the spring and summer ahead of it and in the latter case with the fall and winter ahead.

Variety:

Cane—H 109.
Seed—Both body and top seed—three-eye seedpieces.

Fertilization:

$$\text{With seed}\begin{cases}\text{50 lbs. N per acre from ammonium sulphate.}\\ \text{200 lbs. } P_2O_5 \text{ per acre from superphosphate.}\\ \text{200 lbs. } K_2O \text{ per acre from potassium sulphate.}\end{cases}$$

$$\left.\begin{array}{l}\text{At 3 months—50 lbs. N per acre}\\ \text{At 6 months—75 lbs. N per acre}\\ \text{At 12 months—50 lbs. N per acre}\end{array}\right\}\text{All from ammonium sulphate}$$

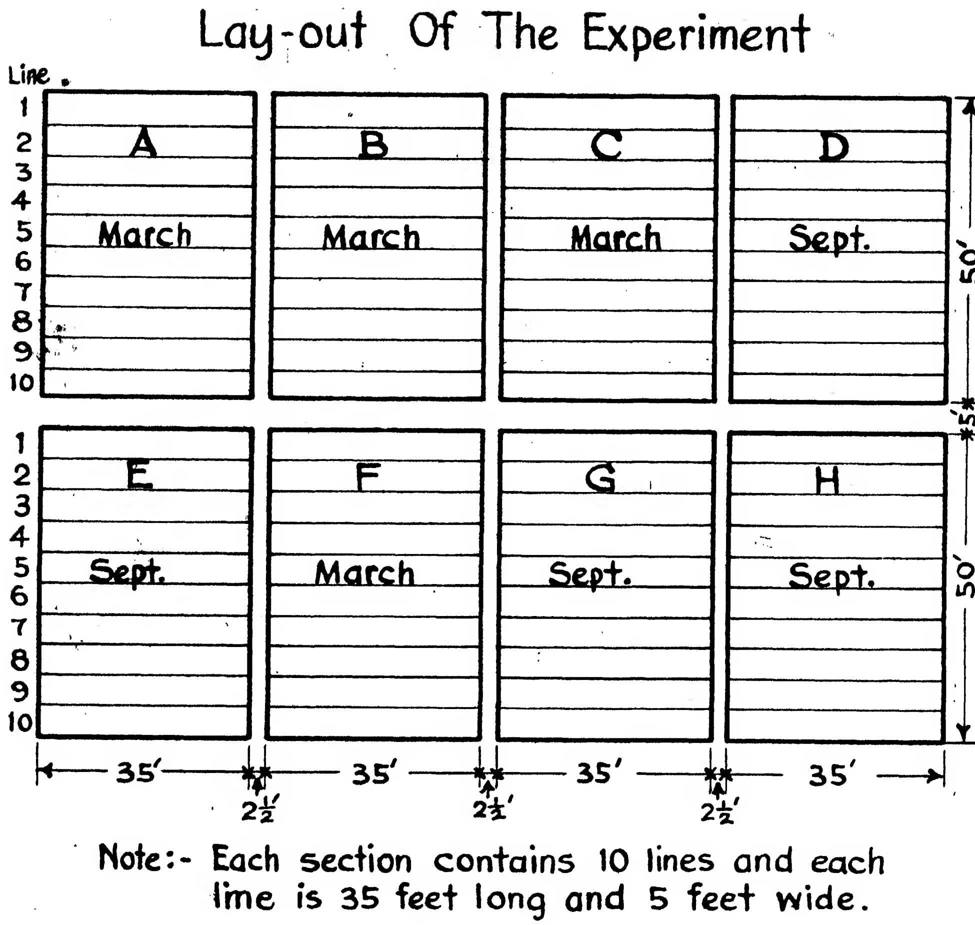


Fig. 1

Thus the total application in each case was 225 pounds N, 200 pounds P_2O_5, and 200 pounds K_2O. These amounts are considered to be optimum under average H 109 conditions on Oahu.

Irrigation: Two inches per application, two applications per week. Allowance was made for heavy showers, light rainfall being neglected. It is believed that 16 inches of irrigation per month represent optimum application of water under the irrigated conditions of this island.

Experimental Procedure

About 35 seedpieces were planted end to end in each row. After about four weeks, the row was thinned out to contain only 35 fairly uniform shoots per line, which gave one shoot per lineal foot of row. This was done to insure a uniform stand of cane in each row. These original shoots, sprung from the seedpieces, are herein called shoots of the first order. Each of these shoots later gave rise to a stool of cane.

These first order shoots were tagged, each tag bearing its serial number, 1 to 35, in each row. Thereafter, at intervals of about two months, we went through the field and labelled all the shoots that had germinated since our previous tagging

and these were successively called the second, third or higher order of shoots. Order in this report, therefore, refers to time of germination only and not to any morphological relationship of one shoot with another.

Suckering

Beginning at one month of age, and thereafter once about every two months, we went through selected rows of cane and counted the number of shoots in each stool. When the cane became too big to render such detailed count physically possible only the total number of stalks in each line was obtained. Particular care was taken not to disturb the growing cane in any way or remove any of the trash from the rows.

March Planting

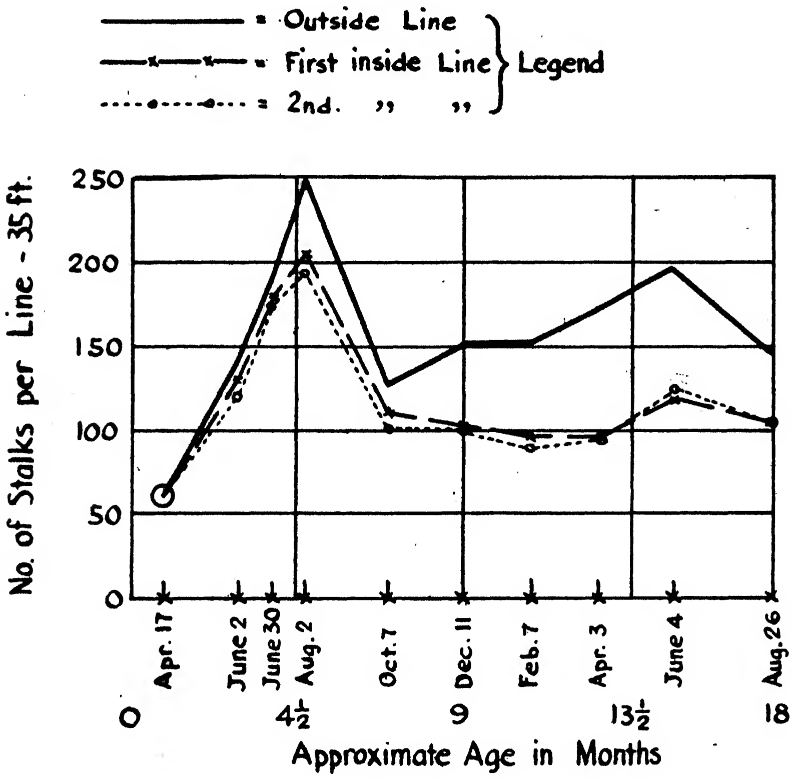
Total number of shoots at various ages: Lines 1 to 3 in Sections A, B, C, and F were selected for shoot counts. The total number of lines were 12, representing 420 running feet of row and 420 stools of cane.

The summarized data are presented in Table I and Fig. 2. We see that at about one month of age this plant field of H 109 had only 35 shoots per line, i.e., there were no suckers.* From then on the number of shoots per line increases up to a maximum of about 4½ months of age. This maximum occurs in the early part of August and is followed by a sharp decline continuing through the fall and winter months. There is a little increase in number in the second season spring, but indications are that even this increase will not be permanent.

* In all the following discussions it should be kept in mind that here the original stools were one foot apart to start with. If there were more of the original shoots per foot at the start or if it were a ratoon field, the progress of suckering might have been different.

Number of Stalks per Line on Different Dates - Sec. A, B, C & F

March Planting



Sept. Planting (Section H Only)

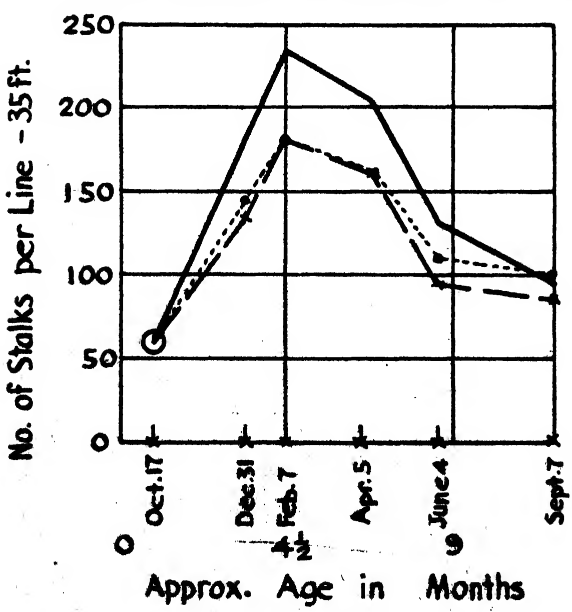


Fig. 2

TABLE I

Total Number of Shoots at Various Dates—Cane Planted March 17, 1931—Average of Sections A, B, C and F

Date	11/4/32	6/2/31	6/30/31	8/2/31	10/7/31	12/12/31	2/7/32	4/3/32	6/4/32	8/26/32
Average of outside lines	35	138	190	249	125	151	150	172	194	146
Average of first inside lines	35	122	173	197	98	100	91	96	123	106
Average of second inside lines	35	133	185	205	110	98	93	97	122	103
Approximate number of months since planting	1	2½	3½	4½	7	9	11	13½	15½	18

September Planting—Section H Only

Date	10/17/31	12/31/31	2/7/32	4/5/32	6/4/32	
Outside line*	35	179	233	207	131	96
First inside line	35	144	181	163	108	99
Second inside line	35	134	179	158	96	87
Approximate number of months since planting	1	3½	4½	7	9	

* It has been explained in the body of the report that this outside line was so only for a short time. As the cane in the adjoining section got big this outside line ceased to be an outside line in the true sense.

Fig. 2 shows only the net results but fails to bring out that in a growing field of cane suckering is a continuous process. Some new suckers are always coming up and others dying, so that the population is never exactly the same, though the total number may remain constant.

In the outside line the progress of suckering is quite different than in the two inside lines. The outside line rises to a greater maximum and the total number does not fall to the level of the two inside lines. Later on in this report we will show that this is due to more space and greater exposure to light obtained by the outside rows.

September Planting

Sections D, E, G, and H were planted in September. At this time, Sections A, B, C, and F had canes already six months old. The end stools in Sections D, E, and G did not get the full amount of sunlight. The shoot count data in these sections are of great interest in showing the effects of shading. However, for the purpose of Fig. 2 only the data from three rows of Section H are summarized, for this is the only section that was not handicapped by the border effect of big cane. The total number of stools here are only 105, but the progress of suckering is identically the same as in the March planting. Starting with 35 stalks per line at one month the number rises to a maximum at about 4½ months and then declines sharply. Contrary to observations reported by others, this decline starts in the beginning of spring and continues through the spring and summer months. Season of planting or season of the year has, therefore, little to do with the general sucker mortality which takes place in every crop. It is also seen in Fig. 2, that in the outside row of Section H, the number of shoots gradually approaches the total of the two inside lines. A study of the layout will show that line 1 in Section H is not an outside line in the sense that line 1 in Sections A, B, or C is. There is only a 2½-foot path separating Section D from Section H. When the cane in Section D got big, line 1 in Section H ceased to have the same space and light as a true outside line.

Factors in Suckering

All evidence points to the fact that suckering is predominantly influenced by light and exposure,* which factors are materially altered inside a cane field by plant competition.

In both plantings, the outside lines have a larger number of suckers than the inside lines. In March plantings, the total number of shoots in the outside lines rises to a maximum of 250 per line or about 7 per lineal foot. In the inside line this is about 5½ per foot. At the time of maximum stooling, the 24 end stools in the 12 lines averaged 9½ shoots per stool but the inside stools averaged only 6 per stool.

The sudden rise in the number of shoots obtained in December for the outside lines of March planted cane is explained by the fact that an adjoining field of cane

* There are indications that it might be the heat that goes with light and exposure more than the photo-chemical effect of light itself that induces suckering.

was cut in October. The outside lines, therefore, received an increased amount of light and space which at once reflected itself in an increased number of suckers in the outside lines.

The inside lines do not show this effect as\will be seen from Table II below. Section F, which did not have the benefit of this exposure, also does not show any material increase in the number of shoots.

TABLE II

No. of Shoots on	Oct. 17, 1931	Dec. 11, 1931	Increase or Decrease
Section A—Line 1 (outside)	124	145	+ 21
2 (inside)	102	98	— 4
3 (inside)	97	99	+ 2
Section B—Line 1 (outside)	114	155	+ 41
2 (inside)	91	106	+ 15
3 (inside)	114	106	— 8
Section C—Line 1 (outside)	127	166	+ 39
2 (inside)	99	99	0
3 (inside)	109	93	— 16
Section F—Line 1	135	138	+ 3
2	98	96	— 2
3	118	93	— 25

It has been observed previously that in September planted cane, the end stools in some of the sections did not receive full sunlight. Some were deprived of early morning light and some of afternoon light. These stools show very irregular and delayed suckering compared with the other stools that received full sunlight. Thus, in Section E, in the end stools which did not receive morning light until about 10:00 o'clock, there were no suckers of the second or higher order until after the fourth month. But the point of interest is this: that the same stools caught up with the others in the number of suckers later on. In other words, suckering was not stopped, but only delayed. This naturally raises a question as to the exact nature of suckering. Do the plants have to have a certain minimum or a balance of some essential factors before they will produce suckers? If this condition is satisfied in two months, suckers will start in two months. If it should take six months for the plants to obtain the minimum or the required balance, suckering may well be delayed for six months. The factors may be total quantity of light, heat or some physiological condition within the plant.

The shoot count data in the September planted cane also indicate that the morning sunlight may be superior to afternoon sunlight in the matter of sucker production.

Plant competition: In a field of cane, plant competition has probably a more direct bearing on sucker production than anything else. We use the word "direct" purposely, for the factor of competition brings in its train other factors such as available space, light, heat, etc. Let us consider a plant field that is just started. It has in our case one shoot to a running foot. There is enough space and light

for it to grow and multiply. At first the shoots have small slender leaves occupying small space, but as the shoots become adult or begin to form millable cane—the leaves become broad and big. There is not enough space for all of the shoots to get their share of light. Some of the better placed shoots continue to grow and others are starved, smothered out of existence. This is about the time when we notice the first big mortality in the number of suckers. This fact operates independently of the seasons; for both in March and September plantings, the mortality starts between 4 and 6 months, about the time when millable cane is forming. But in one case this period comes in the fall months and in the other in the spring and summer months.

After the first big wave of mortality there is a period of fairly stable conditions. Those stalks that have survived continue to grow. Then the time comes when the big canes, being top heavy, begin to lodge. The stable conditions are again altered and where the light penetrates the cane rows new shoots spring up. (Perhaps we should attribute this to the heat that comes with light rather than light *per se*.) If the trash covering is heavy these second season suckers may not be very numerous. But, nevertheless, these suckers are a reality. These new suckers get off to an excellent start, and are very soon competing with the old and fallen cane for light and air. In this struggle sometimes the old one, but more often the younger one, survives. It is now the turn of the old cane to begin dying from top downwards. Here begins the commonly observed rotting of the old cane. This picture is well supported by the data on shoot counts and by observations made at the time of harvest.

Number of Stalks per Foot

It will be noticed that both in the March and the September planted cane, the number of stalks per line is about 95 to 100 or about 2.7 per foot. This figure is essentially the same as reported previously by various workers in these islands. But the point of interest is this, that in the March planted cane, the maximum number was well over 200 per line, while in the September planted cane it was considerably less—but at 12 months or at the time of harvest both plantings had the same number of stalks per line. On the one hand, it shows as though H 109 under the experimental conditions can support no more than 2.7 stalks per foot of line: as though the leaves of these stalks fully utilized all the light and air that are available over a foot of soil, leaving no room for further leaf production. (In canes with smaller leaves this number should undoubtedly be greater.) On the other hand, it raises the question: Is it of any advantage to have a large number of suckers to start with if we always end up with the same number? Is the March planting better than the September planting?

Sucker mortality is a natural phenomenon and we shall not possibly be able to stop it, but nevertheless the writer feels that this is at best a necessary evil, that sucker mortality represents much wasted effort and very probably some wasted material.*

* There is some evidence that at least part of the mineral matter may move away from the dying shoots to the growing ones of the same stool. But can this be true of the complex carbohydrates and protein material of the dying shoots?

Border Effect

Fig. 2 shows that a change in the exposure outside of the field affects the outside lines only. Even the first inside lines of March planted cane do not show the fluctuations that the outside lines do. It would, therefore, appear as though one single line of cane was as well able to protect an inside line from extraneous influences as two lines of cane.

Weight of Millable Cane

March planting: Beginning at six months and continuing thereafter at intervals of two months, we harvested two lines of cane. At the time of harvest,

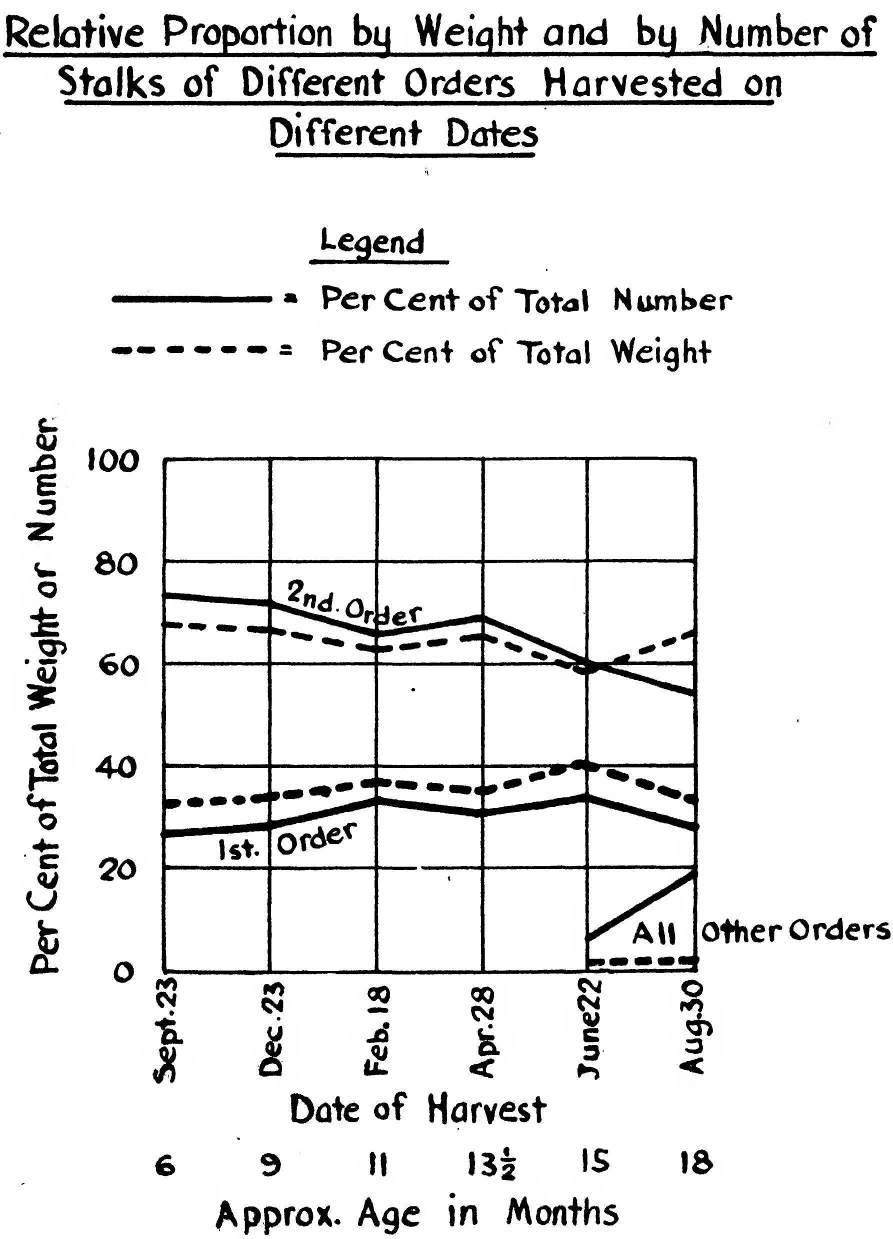


Fig. 3

each stool was cut separately and each stalk weighed, so that we know not only the total weight of cane per row at different ages, but also the relative proportion of shoots of various orders and the weight of cane of each of these orders.

Kind of stalks harvested at different dates: Table III and Fig. 3 show the relative proportion of the different kinds of stalks harvested to date. Here we find that the crops consist almost entirely of the first and second order of stalks. Once in a while we have harvested a stalk of the third order, and more recently a few second season suckers or stalks of the fifth or higher order, but the proportion of the total weight made up by these later shoots has not as yet been of any magnitude. As to the distribution by number, there is in general one stalk of the first order and 2 to 3 of the second order, and perhaps a small fraction of one of the other orders. This picture might have been different with closer planting of the original shoots.

TABLE III

Weight and Number of Stalks of Different Order Expressed as Percentage of the Total Weight or Total Number of Stalks

Harvesting Dates	1st Order Weight	1st Order Number	2nd Order Weight	2nd Order Number	3rd or Higher Order Weight	3rd or Higher Order Number	Total
Sept. 23, 1931..........	32.0	27	68.0	73	...	..	100%
Dec. 23, 1931	33.0	28	67.0	72	...	..	100%
Feb. 17, 1932..........	36.3	33	63.0	66	0.7	1	100%
April 28, 1932..........	34.0	31	66.0	69	...	..	100%
June 22, 1932..........	40.0	34	59.0	60	1.0	6	100%
Aug. 30, 1932..........	32.0	28	66.0	54	2.0	18	100%

In other words, most of the cane harvested up to 18 to 20 months consists of stalks that came up within the first three months after planting. This shows that the mortality was almost entirely confined to suckers of the third or higher order.

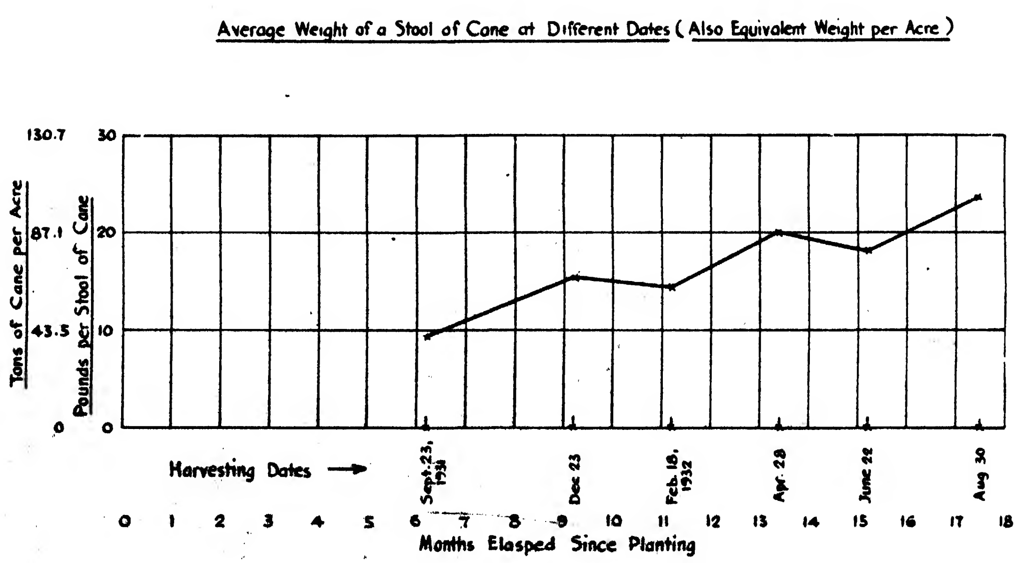


Fig. 4

Weight of millable cane: Since we have in each row 35 stools to start with, we can express the weight at harvest as the average weight of a stool of cane. An idea of the weight per acre can be obtained by multiplying the individual stool weight by 8712.

Table IV and Fig. 4 show the weight of millable cane at different dates. There is a steady trend of increase in weight up to 18 months of age. The fluctuation in weight appears to be entirely correlated with the fluctuations in the weight of the second order stalks, which in turn is correlated with the number of second order stalks harvested at different dates (see Fig. 3). However, these fluctuations are well within the allowable limit of variation to be expected in any field experiment.

TABLE IV

Average Weight of Stool at Different Dates

Harvesting Date	Approximate Age of Field	Average Weight of Cane in One Stool in Pounds	Calculated Weight of Millable Cane per Acre in Tons	Weight of Green Top and Leaves per Stool in Pounds
Sept. 23, 1931........	6	9.50	41.4	6.40
Dec. 23, 1931........	9	15.60	68.0	...
Feb. 17, 1932........	11	14.47	63.0	...
April 28, 1932.......	13½	19.81	86.3	6.93
June 22, 1932........	15	18.15	79.1	4.37
Aug. 30, 1932........	18	23.43	102.1	4.411

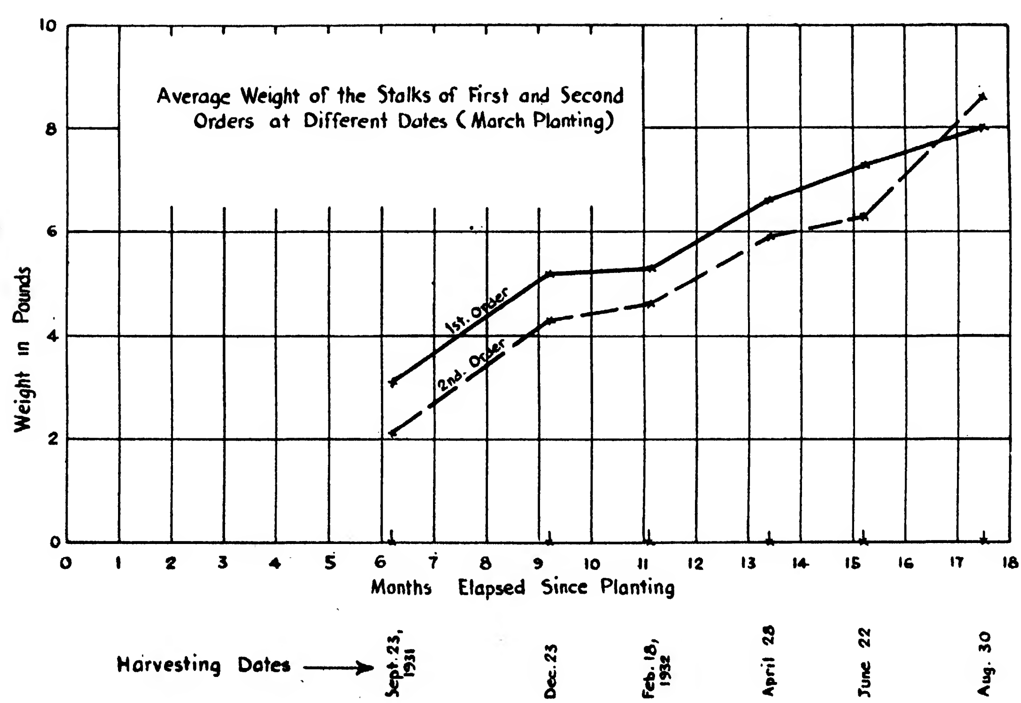


Fig. 5

Increase in weight of the stalks of different orders: Table V and Fig. 5 show the average weight of the first and second order stalks at different dates. It is surprising how regular and how similar is the increase in weight of the stalks of these two orders between different dates. The increases are almost parallel till the fifteenth month. However, the last harvest indicates as though the first order stalks are beginning to slow down, while the second order stalks are still proceeding at a rapid rate. In going through the detailed harvesting data, it is observed that there is greater mortality among the first order stalks than in the second order stalks, which probably accounts for this differential rate of growth. The mortality of the tops of big cane was not in evidence until after the fourth harvest at 12 months. This is to be expected, for this mortality undoubtedly followed the lodging of the big cane at about that age and the consequent shading out by other and more vigorously growing suckers.

TABLE V

Average Weight of First Order and Second Order Stalks on Different Dates

Harvest Date	Approximate Age	Weight of 1st Order Stalks (Lbs.)	Weight of 2nd Order Stalks (Lbs.)
Sept. 23, 1931....................	6	3.07	2.06
Dec. 23, 1931....................	9	5.21	4.13
Feb. 17, 1932....................	11	5.28	4.57
April 28, 1932....................	13½	6.63	5.90
June 22, 1932....................	15	7.20*	6.29*
Aug. 30, 1932....................	18	8.03*	8.63*

But even among the second order stalks there is some mortality after the fifteenth month. Beginning at about that age there will probably be a continuous and mounting loss of cane due to the gradual death and decay of the old stalks. Whether the new suckers will make up for this loss is yet to be seen.

September Planting

We have had only two harvests to date from this planting and, therefore, we need to spend very little time in discussing the results. The data indicate, however, that in Section H (where there were no border effects) the average weight of stool compares well with the weight of the March planted cane at comparable ages. So far there is no difference that could be attributed to season of planting—but later harvest may tell a different story.

It is also of great interest to note that the end stools in Section E (which stools did not receive the morning sunlight) average less in weight at each harvest than the other stools in the line (Table VI). The difference of one and a half pounds per stool in favor of the more exposed stools, as shown by the harvest at 12 months, would amount to a difference of nearly 6½ tons of cane per acre. Will this difference go on increasing as the crop gets older, or will the end plants

* These figures would be higher if the dying or rotting stalks were not included in the average.

overcome the handicap of the earlier months? Right now, most of the canes have lodged and the end plants should have about the same sunlight as the other plants.

TABLE VI

Weight of Millable Cane per Stool at Different Dates

	July 1, 1932	Sept. 8, 1932
Shaded end stools................................	9.0 lbs.	11.62 lbs.
Exposed stools	10.56 lbs.	13.21 lbs.

Quality of Juice

A study of the composition of a cane crop is essential for an understanding of the factors bearing on juice quality, if for nothing else.

What are the components that make up the average quality ratio of a crop? What is the quality of juice in stalks of different orders? Is second season suckering a real detriment to good juice? In the same cane, how does the top part differ from the bottom part? Where lies the difference in juice quality between a vigorously growing cane and a cane that is slowing down growth and shortening its green vegetative part? These are pertinent questions, but our study of juice quality cannot progress without an answer to them.

At each harvest the stalks of different order were segregated and the juice extracted by a three-roller mill and analyzed. No attempt was made to draw representative samples, but the total quantity of cane was run through the mill. Occasionally one or two extra lines of cane were harvested to gain additional information on some points.

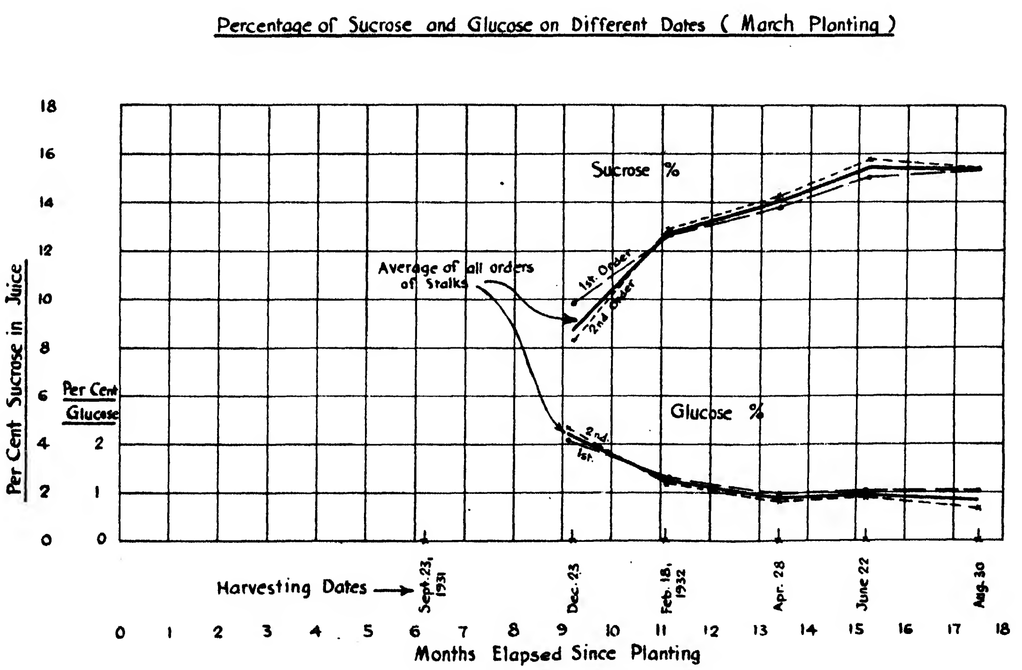


Fig. 6

Also, no attempt was made to withhold irrigation water to ripen cane. The cane received full irrigation right up to the day of harvesting. This fact must be borne in mind in scrutinizing the data.

March Planting

Difference in juice quality in stalks of various orders: Table VII and Fig. 6 show the percentage of sucrose and glucose in juice of the various orders and also the true average for stalks of all orders. It is seen that the average for all stalks is primarily influenced by the average of the stalks of second order. This is to be expected because the second order stalks constitute about two-thirds of the total weight of all stalks. The second order stalks are also seen to be about equally rich in sucrose and in glucose as the first order stalks. This fact is significant when we consider that the first order stalks are in reality about a month to two months older than the second order stalks. Where data are available on stalks of higher order, it is generally found that if we compare juice quality in relation to true age (reckoned from the time of germination) then the stalks of higher order prove superior. In other words, at true comparable ages the later stalks have more sucrose than the early stalks.

TABLE VII

Per Cent Sucrose in Juice in Canes of Various Orders at Different Dates

	Date of Harvest				
	12/23/31	2/18/32	4/28/32	6/22/32	8/30/32
First order	9.75	12.65	13.71	15.09	15.27
Second order	8.14	12.83	14.13	15.69	15.37
Average for all* orders	8.60	12.74	13.99	15.37	15.25

Per Cent Glucose in Juice

	12/23/31	2/18/32	4/28/32	6/22/32	8/30/32
First order	2.04	1.33	.97	1.02	1.01
Second order	2.32	1.21	.78	.86	.64
Average for all* orders	2.24	1.25	.84	.93	.76

The harvesting data presented so far consisted of inside lines only, from which we did not get much data on canes of higher order. But we knew from shoot counts that the outside lines had generally more suckers representing many different orders. So we harvested an outside line (Row 1 of Section B) to obtain juice figures from as many different orders of cane as possible. The data, presented in Table VIII and Fig. 7 show that there is a general decrease in the percentage of sucrose and a very regular increase in the percentage of glucose as we go from stalks of first order to stalks of higher order. Under ideal conditions of plentiful light and space and hence little deterioration of old cane, we should expect to find it so. But where the old cane is dying and deteriorating, we shall probably find that the later suckers will, on the average, be richer in quality than the early canes.

* The grand average includes juice from stalks of other and higher orders.

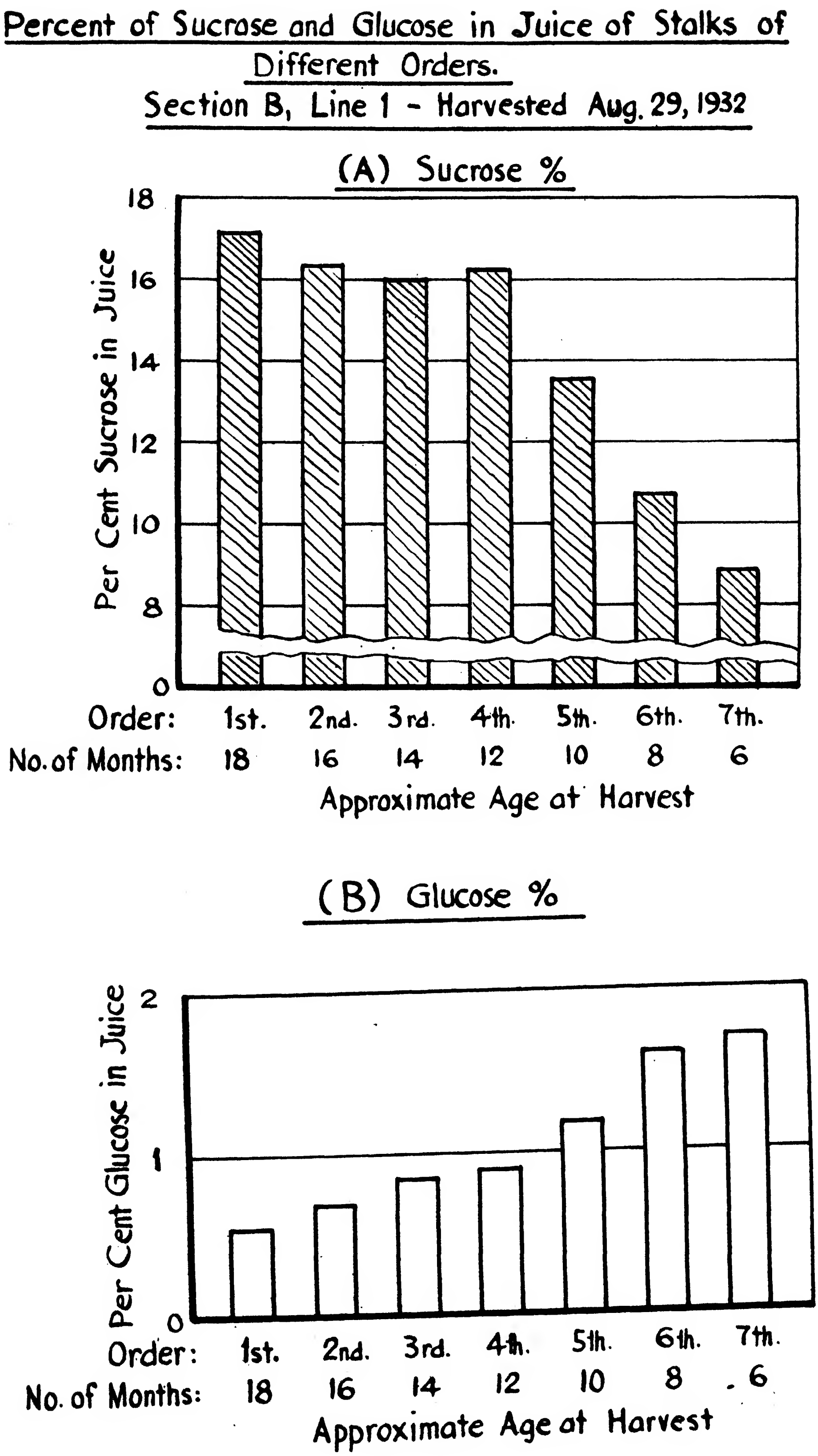

Percent of Sucrose and Glucose in Juice of Stalks of Different Orders.
Section B, Line 1 - Harvested Aug. 29, 1932
(A) Sucrose %
Per Cent Sucrose in Juice
18
16
14
12
10
8
0
Order: 1st. 2nd. 3rd. 4th. 5th. 6th. 7th.
No. of Months: 18 16 14 12 10 8 6
Approximate Age at Harvest
(B) Glucose %
Per Cent Glucose in Juice
2
1
0
Order: 1st. 2nd. 3rd. 4th. 5th. 6th. 7th.
No. of Months: 18 16 14 12 10 8 6
Approximate Age at Harvest

Fig. 7

TABLE VIII

Quality of Juice in Stalks of Different Orders in an Outside Line

Order of Stalk	Per Cent Sucrose	Per Cent Glucose	Approximate True Age at Harvest	Per Cent Sucrose ÷ True Age at Harvest
First order	17.12	0.60	18	0.95
Second order	16.29	0.72	16	1.02
Third order	16.08	0.84	14	1.15
Fourth order	16.16	0.91	12	1.35
Fifth order	13.54	1.19	10	1.35
Sixth order	10.68	1.60	8	1.34
Seventh order	8.92	1.72	6	1.49

Differences in juice quality in the different parts of the same stalk: From a practical standpoint, the differences in the quality of the same stalk at different ages may be of even more significance than the difference between successive orders. How does a cane mature? Is the sucrose or glucose content the same in the different parts of the cane? How do seasonal influences or cultural treatments affect the various parts of the cane? With these thoughts in mind, we harvested another outside line of cane (Row 1, Section B). At harvest we segregated the stalks of various orders and each stalk was divided into the following sections, working from the top downward:

(1) Non-millable top with leaves;
(2) Millable cane.

The millable cane was further divided into four sections:

(a) The green-leaf part;
(b) The top 4 feet of cane remaining after the removal of the green leaf part;
(c) The extreme bottom 4 feet, i.e., 4 feet of cane right above the ground;
(d) The section between b and c, herein called the middle section.

The green-leaf part is defined as that part of cane where the attached leaves are still wholly or partly green. In actual practice the green-leaf part ended at a point where on removing the leafsheath no scar was left on the stalk. It is believed that since to this section only are the green leaves attached, this would also be the zone of most active sucrose accumulation. The results obtained appear to justify such belief.

The cutting of cane according to the above scheme, appears to have merit, especially for the purposes of fundamental study, over the general practice of cutting cane into equal sections working from the bottom upward. Let us consider the case of a sucker which is 8 months old and contains, say, only 4 feet of cane. In the old practice, we would be comparing the bottom of this young cane with the bottom of an old, say, an 18-month cane. One can easily see that the comparison would hardly be valid, for the simple reason that the two sections did not grow at the same time. In the present scheme, this sucker would only have

a top section (for we shall work from top downward) and this will be compared with the top section of an old cane. There is greater probability that both these sections were growing at the same time and, therefore, were equally influenced by environmental factors. Thus it happens that where the length of cane is less than 8 feet we have obtained only top and middle sections—and from our point of view this cane consists of no section comparable to the bottom section of a 12- or 14-foot cane. The data are presented in Table IX and Fig. 8.

In regard to sucrose per cent, we see at once that in all orders of stalk there is materially little difference between the different sections of the dry-leaf part of

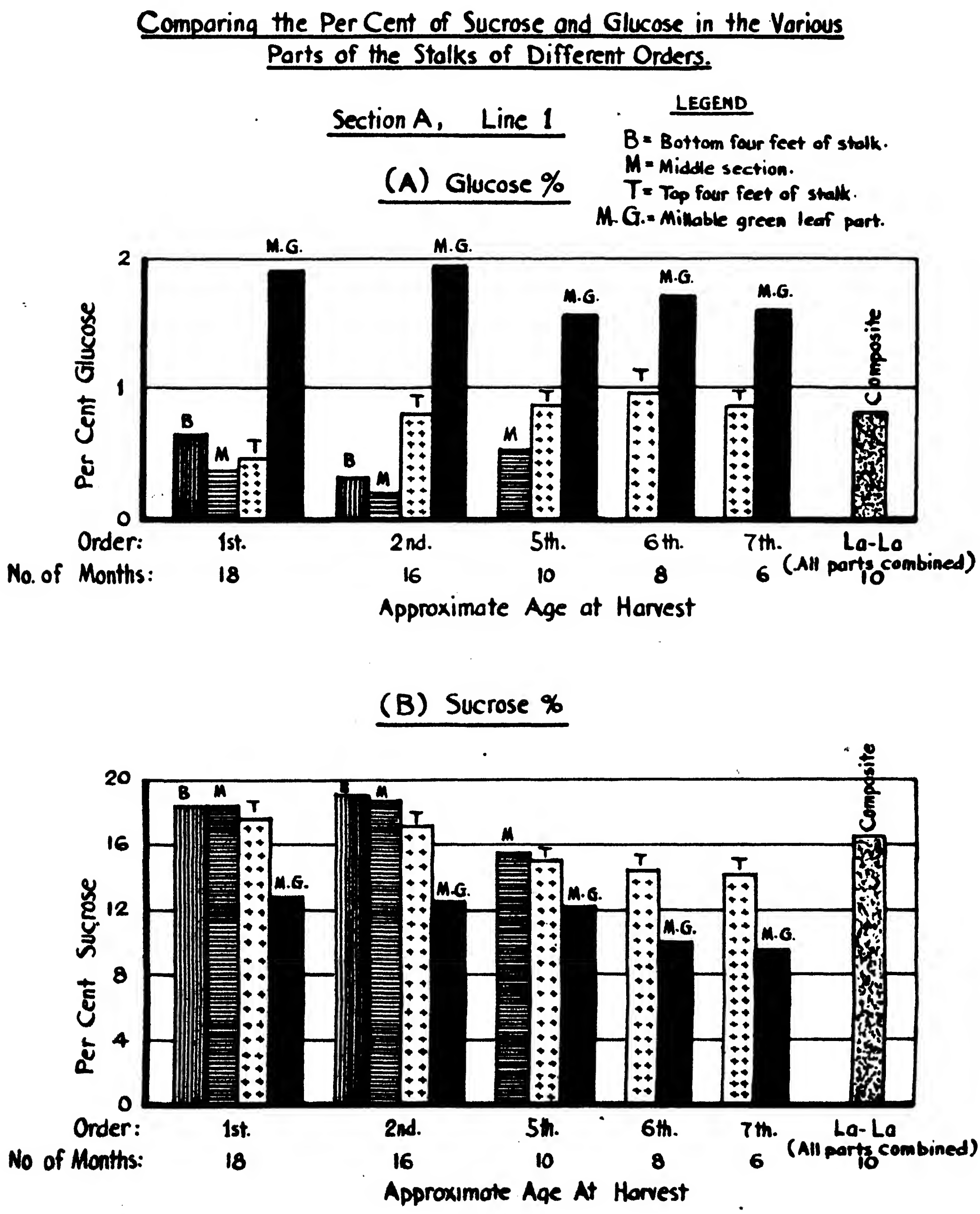


Fig. 8

the millable cane (i.e., the part of millable cane without the green-leaf section). But from there to the green-leaf part, there is a sudden decline in sucrose content. In other words, we may say that the green-leaf section is still in the process of gathering sucrose, while the dead-leaf part has reached a certain state of maturity. We do not imply that the level of sucrose in the dead-leaf part will not rise any further. In fact, it does rise to a certain extent, but what we do emphasize is this, that the green-leaf part is the one that is capable of the most advancement in sucrose; this is the part that is growing now and will be comparatively more susceptible to present environment and treatments than any other part.

The relative proportion of the green-leaf part to the dead-leaf section is, therefore, a matter of very great importance from a practical standpoint; for the average juice of a stalk is a composite between these two sections. The superiority of an old cane over a young sucker is undoubtedly due in a large measure to the fact that in young, vigorously growing suckers the green-leaf part may constitute fully one-third of the whole millable stalk. In the old cane it may be, and generally is, about one-eighth or one-tenth of the whole stalk. Even if the sucrose content in the dead-leaf and green-leaf sections of the two canes were identical, we shall find a great difference in the average juice quality of the two canes, much in favor of the old cane. The data obtained are similar to observations made originally in Coimbatore, India, and are also substantiated by other data obtained in this experiment.

Now the question will arise in one's mind as to what actually happens when we withhold water from the maturing cane. We have seen that the dead-leaf section had reached a certain state of maturity long before harvest time and the accumulation of sucrose in that part was mostly influenced by conditions of environment and culture that is now past history. Could it not be that in ripening off we are concentrating our efforts primarily on the green-leaf section? True, the withholding of water may drive off a small percentage of moisture from the cane, but probably the greatest thing it does is to stop new growth, and at the same time add more to the dead-leaf section by reducing the size of the green-leaf section.

These discussions will also raise the question if our pre-harvest sampling of cane may not be made more reliable by obtaining information on the relative proportion of dead-leaf and green-leaf parts of representative stalks. It is quite probable that we may be able to substitute a few physical measurements of the different parts of stalks for actual juice analysis; and therefrom get the desired information on the progress of ripening of a field.

Another interesting fact emerges out of Table IX and Fig. 8, that the lalas (side shoots) on canes of the first and second order have a juice quality more approaching the average of the stalks on which they are growing than the young suckers with which these lalas are comparable in age. This would indicate as though the lalas formed an integral part of the big cane and maintained the same level of sucrose concentration as the old stalks.

Point of maximum sucrose content: In this 18-month-old cane the maximum concentration of sucrose is still in the extreme bottom section. These results are

contrary to the accepted belief that as the cane grows old the point of maximum richness invariably moves towards the top. However, later harvests may give different results.

Glucose in the various parts: As in the case of sucrose, the concentration of glucose also changes suddenly as we move from the dead-leaf to the green-leaf section. This sudden increase in the amount of glucose in the green-leaf section again points to the conclusion that this is the part of cane where active processes are going on. It is interesting to note that the lowest concentration of glucose is not in the extreme bottom section, but in the "middle" section of the first and second order stalks. This may indicate a breaking down of sucrose in the extreme bottom, due to age or to demands made by the rhizome and the roots.

TABLE IX

Per Cent of Sucrose and Glucose in the Different Parts of the Stalks

Section	Sucrose Per Cent				Glucose Per Cent			
	A Green-leaf Part	B Top 4′ of Cane	C Bottom 4′ of Cane	D Middle Section	A Green-leaf Part	B Top 4′ of Cane	C Bottom 4′ of Cane	D Middle Section
First order	12.85	17.52	18.51	18.34	1.882	.435	.661	.339
Second order	12 52	17.23	18.97	18.77	1.955	.797	.327	.197
Fifth order	12.18	15.19	....	15.52	1.540	.874	...	.500
Sixth order	9.98	14.30	....	....	1.698	.991	...	...
Seventh order	9.58	14.22	....	....	1.576	.861	...	...
Lala-combined green-leaf and dead-leaf part				16.38			.791	

September Planting

As stated previously, we have had only two harvests so far from September planted cane. The advancement in richness of juice of various orders appears to be following the same trend as in the March planted cane. In Section E, where part of the cane did not receive full sunlight in the earlier stages, the quality of juice appears to be very inferior to that of the stalks which were more fully exposed. This difference is seen both in the green-leaf and the dead-leaf sections of the two groups of stalks (Table X). Thus in addition to being less in weight per stool, these "partly shaded" stools are also lower in quality. Similar conditions probably exist on some of our plantations which are deprived of sunlight during part of the day.

TABLE X

Per Cent Sucrose in the Juice of Shaded and Unshaded Stools
Harvested September 8, 1932

	First Order		Second Order	Third Order
	Green-leaf Part	Dead-leaf Part		
Shaded stools	8.46	12.59	10.88	11.76
Exposed stools	10.15	13.83	12.84	12.61

Conclusions

In the foregoing pages, data have been produced to show that suckering is more or less a continuous process in a field of cane and that it is affected mainly by exposure to light and plant competition. It has been pointed out that a crop generally consists of cane of different age groups, which are materially different from each other both in quality and total quantity. It has also been shown that the average juice quality of a crop is a composite between the stalks of different ages and that within the same stalk this quality is also a composite between the dead-leaf and the green-leaf parts. It is suggested that only through these conceptions of the elements of a crop can we hope to gain a clearer understanding of the interrelated problems of cane tonnage and quality.

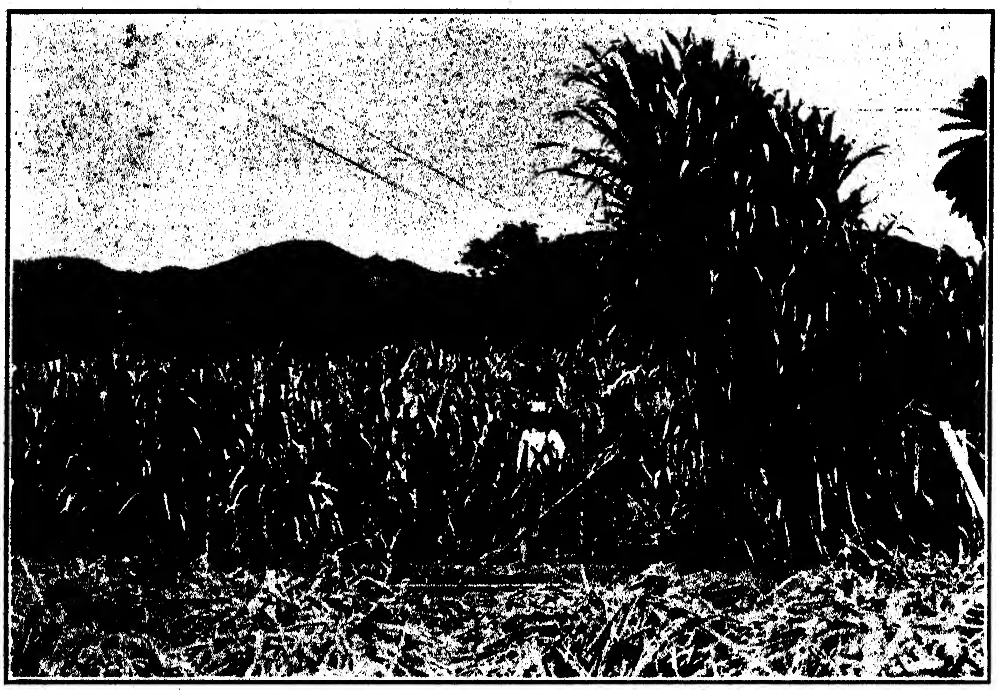


Fig. 9. Showing the March planted cane (big cane) to the right and the September planted cane (small cane) to the left. The right end stools of small cane were shaded in the forenoon by the big cane. These stools were late in stooling out and at harvest the stalks weighed less and had less sucrose than the stools towards the left which received full sunlight.

Fig. 10. All the stalks shown in the picture grew originally from one single eye of cane. This one stool is from an outside row of cane and it contains stalks ranging in age from 4 months to 18 months. This is an extreme case to be sure, but this illustrates that under favorable conditions of light, space, and food, suckering is a continuous process in a field of cane.

Fig. 11. Showing the quantity of cane of different orders harvested from one inside line of cane in this experiment. At the time of harvest the field was 20 months old.

Fig. 12. This illustrates that in a first season cane, the green leaf part (the part containing little sucrose and much impurity) constitutes only a seventh or an eighth of the whole stalk. In the second season sucker, this green part is fully half as much as the whole stalk. The relative proportion of this green part of the stalk to the rest of the stalk has a very important bearing on the average richness of the whole stalk.

Fig. 13. The stick to the left is a sucker of the fifth order. At the time of harvest it was 10 months old. To the right is a lala growing from a first season cane, only part of which is shown. This lala is also 10 months old, but the richness of juice of the lala is very much higher than the fifth order shoot with which it is comparable in age and nearly approaches the richness of the first season cane on which this lala is growing.

Fig. 14. Here are three stalks in different stages of vigor as shown clearly by the manner of growth of the tops—by the spread and number of leaves, etc. The most vigorous one on the extreme left has a large green leaf section, the one on the extreme right a very small green leaf section of millable cane. It is suggested that the maturity of a stalk can well be judged by noting the length of this green leaf part and the proportion it bears to the whole stalk.

Further Observations Upon the Relation Between Cane Elongation and Soil Moisture

By H. A. Wadsworth

Introduction

In a previous paper (6) the writer in cooperation with U. K. Das pointed out that no visible physiological distress was noted in sugar cane when the moisture in the soil supporting the plant reached or dropped somewhat below the permanent wilting percentage. Most other plants that have been studied, except the xerophytes, give evidence of moisture deficiency by some symptoms of flaccid tissue such as drooping or rolling leaves at and below this critical soil moisture constant.

The early studies with cane indicated that an exception must be noted with this plant. Although some physiological disturbances might be expected at the soil-moisture content, known as the wilting percentage, this disturbance was by no means sharply defined. Cane plants in soils considerably below the permanent wilting percentage, showed little sign of flaccid tissue and any leaf rolling, which did occur during the middle of the day, was eliminated during the conventional exposure to the saturated atmosphere which is required by the usual procedure (1).

However, it was noticed that the rate of growth, as measured by the elongation of the primary shoot, was significantly reduced when the soil-moisture content was near the permanent wilting percentage for the particular soil, as determined with sunflowers in the conventional manner.

Further and more elaborate investigations of the responses of sugar cane to soil moisture were undertaken by H. R. Shaw and the writer at Waipio. Here under the conditions existing in tanks in the open the assumption that cane elongation proceeded at a uniform rate until the soil-moisture was reduced to the wilting percentage and then ceased, to be resumed only upon the addition of water to the soil, seemed justified. Details of the observations leading to this conclusion were presented at the annual meeting of the Hawaiian Sugar Planters' Association in 1930.

Continued interest by Mr. Shaw and others has demonstrated that the simple conception that the normal rate of growth is suddenly reduced to no growth at all when the soil moisture falls to the wilting percentage need not be true. As a result of work in the H. S. P. A. greenhouses, Shaw and Matsusaka (5) note a soil-moisture zone of 3 or 4 per cent lying near the permanent wilting percentage in which cane growth may be seriously handicapped. The sharp discontinuity between normal growth and no growth is not found by these workers, this discontinuity being replaced by a transitional curve of some considerable length. Observations of elongation were apparently made at daily intervals. Bond, working with plants in the field at Ewa, reports a similar decrease in the rate of growth immediately preceding complete cessation.

The interest evidenced at the annual meetings of the H. S. P. A. in 1930, when these results were presented, has prompted a continued study at the University of Hawaii. Many refinements in the methods used in measuring elongation were attempted. The possibility of using a slow speed moving picture camera to record growth was explored but abandoned.

The Optical Lever

Although the optical lever has apparently never been used in measuring plant responses, the device in a modified form proved suitable in measuring the elongation of the primary shoot of potted plants in the greenhouse. Essentially, the lever consists of a small circular mirror mounted vertically upon a brass block from the bottom side of which two sharp steel pins extend. A section of light brass rod, one end of which is bifurcated, extends through the block and is normal to the mirror. In operation the lever is mounted on a steel bar carrying depressions for the steel points mentioned above, while an ordinary household pin secures the point at which growth is to be measured between the two sections of the bifurcated end. When properly made, the lever balances upon its supports and the point in the plant perforated by the pin is neither under tension nor compression. A close up of two levers applied to a single cane plant is shown in Fig. 1.

It is evident that the vertical displacement of the pin through the plant will result in a deflection of the mirror and that the magnitude of this deflection may be observed by a laboratory telescope and scale. In the present installations a paper scale, divided into millimeters, is mounted on the concave arc of a circle with a radius of 100 cms. The arc with its scale is mounted in the plane normal to the mirror. A laboratory telescope, so mounted that its center line is at the same height as the center of the mirror, carries the image of the scale in its field. The cross hair in the telescope provides a basis for measurement. The details of the parts and their assembly are shown in Figs. 1 and 2. In the upper lever illustrated in Fig. 1, the distance from the mirror to the pin is 10 cms., while that from the mirror to the scale is 100 cms. This ratio of 1:10 must be increased twofold because of an optical factor which may be readily demonstrated. The apparent magnification of growth by the upper lever in Fig. 1 is 20 times. The geometry of the optical system and its limitation has already been described (7).

It is also evident that observations of the vertical displacement of an arbitrary point on the leaf bundle gives no direct evidence of the vertical displacement of the last visible ligule since several feet of leaf may be produced during the formation of a few inches of cane. Consequently, two levers were used on each plant. One of these, with an effective ratio of 1:20, has already been described. A second, the lower in Figs. 1 and 2 and built for a ratio of 1:40, was attached to the ligule in such a way that the vertical displacement of the ligule might be observed through a second telescope. Observations on rates of growth are classified as leaf displacement and ligule displacement. Due recognition must be made of the differences in the optical ratios involved.

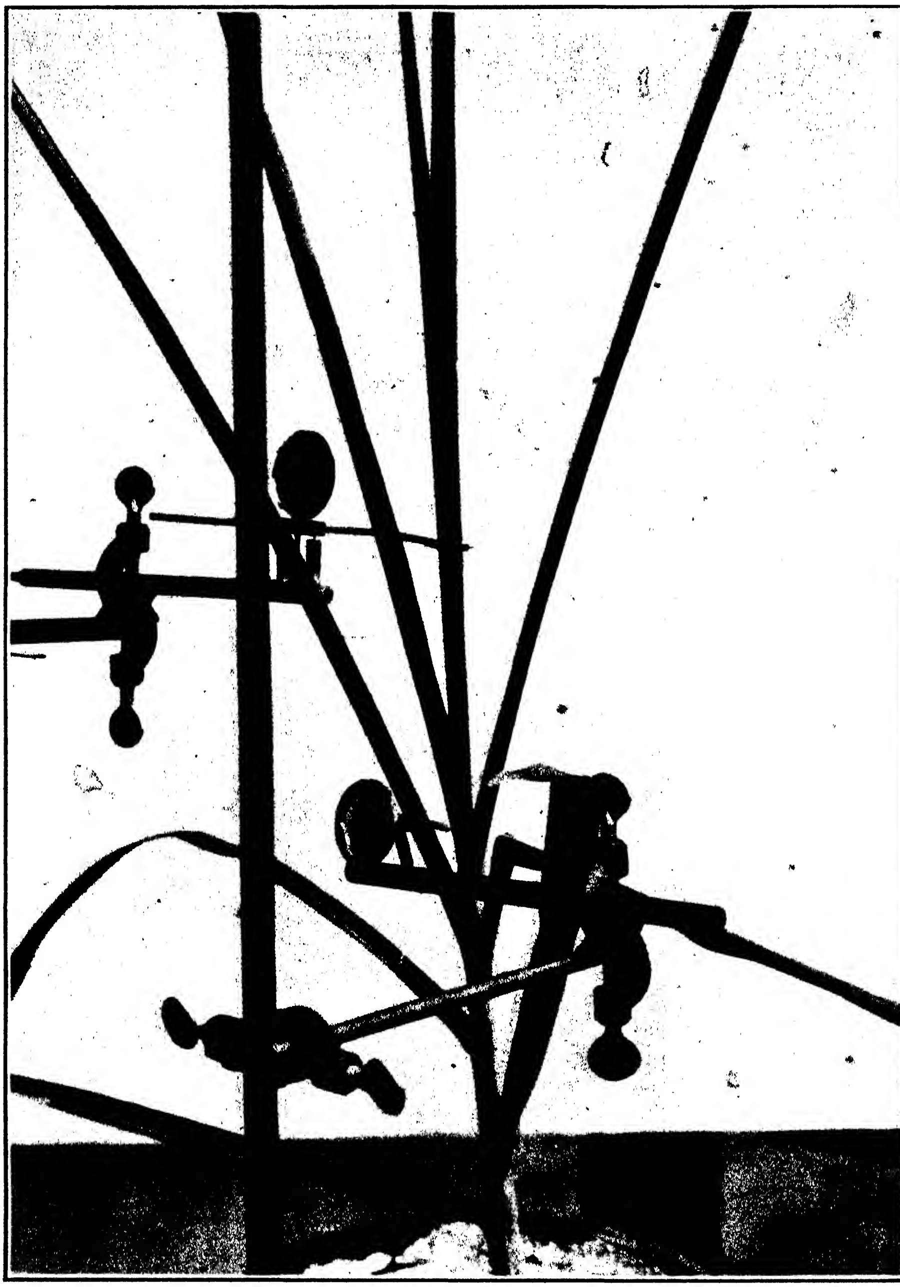


Fig. 1. The optical lever as used in studies of cane elongation. The upper lever provides a 20-fold magnification of rate of growth. The lower lever on the ligule gives a magnification of 40. (University of Hawaii photograph.)

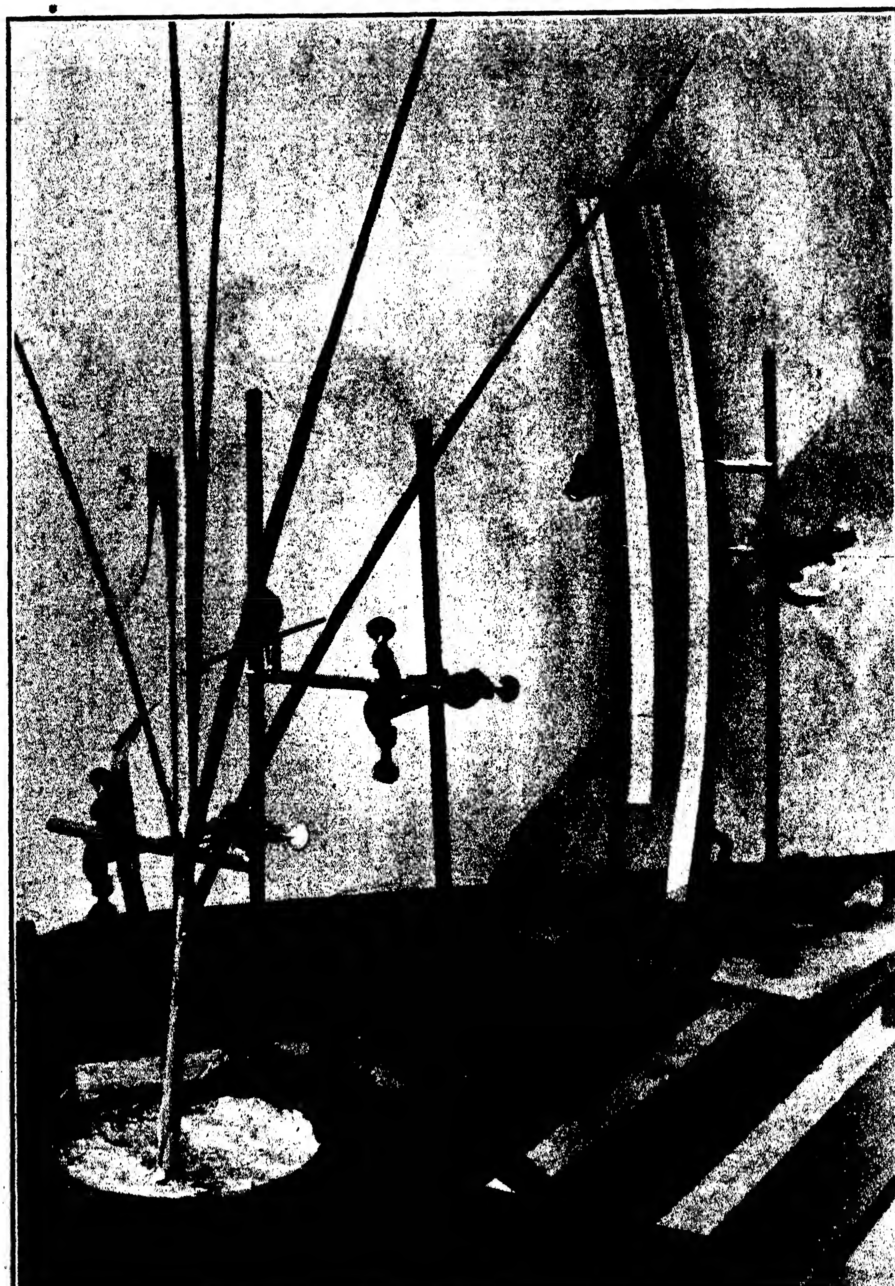


Fig. 2. General view of lever assembly, showing positions of telescopes and scales. (University of Hawaii photograph.)

The Observations

Soil for the specimen plant was secured from the Waipio substation of the H. S. P. A. and exhibited a moisture equivalent of 29.7 ± .16. This material was carefully screened and placed in a specially prepared copper container with a diameter of 10 inches and an effective soil depth of 15 inches. A healthy plant of cane (variety H 109) was transplanted from a two-months-old planting to the soil mass and the system irrigated to maximum field capacity. After three weeks, which were allowed for the reestablishment of the root system, the soil was irrigated once more, the soil-surface tightly covered with lead foil to reduce surface evaporation, and observation begun. In general, observations were made at least five times a day during the first month of observation and twice daily, namely, at 7:00 a. m. and 4:00 p. m., for the rest of the period. In each case the position of the reflected beam was noted on the scale and the deflection of the beam during the period computed as a difference. The continuous summation of these vertical displacements naturally gives the growth history with great precision, in view of the effective magnification. Frequent adjustments of the mirror were necessary since the reflected beam, during normal growth, would swing over the entire range of the scale in something less than 12 hours. In general, weighings were made at the first observation in the morning, normally at 7:30 a. m., although additional weighings at 4:00 p. m. were added during the second half of the period of observation.

Results

The complete data for the entire series of observations, extending continuously from February 21 to April 9, cannot be presented within practicable limits. Nor are they necessary. A study of this material, however, indicates that the total elongation for a 24-hour period is essentially constant for a considerable time after each irrigation of the soil mass as Shaw and Matsusaka (5) have already pointed out. In the present case the average rate of elongation during the first half of the first series of observation was 89.2 ± 6.0 scale centimeters per day. The corresponding result during the second half of the same series was 89.4 ± 5.6 scale centimeters per day. At the end of this period of essentially uniform elongation and at a moisture content somewhat above the permanent wilting percentage, a reduction in growth accomplished during a 24-hour period sets in and a gradual curtailment of growth brings the elongation to a stop within a few days. At the end of this period no growth is observable nor can growth be resumed without an application of water.

This aspect of the study may be illustrated by Fig. 3, which gives the results of detailed observations upon leaf extension between 7:00 a. m. March 21 and 4:00 p. m. March 28. During this period the rate of growth declined from normal growth to no growth, the transition curve extending from March 23 to March 26. The curve in Fig. 3 is perfectly typical of all cases involving a similar soil moisture range.

It will be noted, in Fig. 3, that the smooth curves heretofore used to express the rate of growth can no longer be used if more than one observation a day is

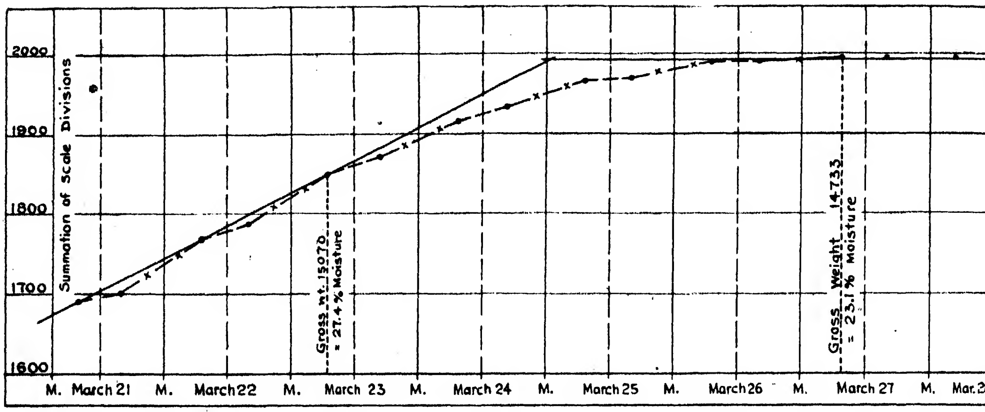


Fig. 3. Length growth history of sugar cane in soil near the permanent wilting percentage. The cane is under greenhouse conditions.

plotted. The first three morning observations are in themselves collinear as are the corresponding observations at four in the afternoon. But no single straight line can contain all six points. And the same relation would be noted if the curve were extended to the left, that is, into dates prior to March 21. In the figure the rate of growth during the heat of the day is indicated by a broken line, while the rate during the night is indicated by a broken line with crosses. The differences in slope are evident and it becomes apparent that under greenhouse conditions the rate of growth, even at high moisture contents, is greater during the night than during the day. As the moisture content falls, both rates are reduced and on March 26 there was no growth in either period. The flat arm of the growth curve previously noted for low moisture contents naturally results.

The observations plotted in Fig. 3 relate to the first growth cessation in a series of three. Reduced daily elongation was first noted at a gross weight of 15,070 grams, which, in view of the tare weights involved, indicates an average moisture content of 27.4 per cent. Elongation essentially ceased at a gross weight of 14,733 or 23.1 per cent moisture.

These data together with corresponding observations for the other two periods of retardation, are given in Table I.

TABLE I

Critical Weights, Dates and Soil-Moisture Percentages for Three Successive Periods of Growth Retardation With Sugar Cane

	Retardation Begun			Retardation Ended		
	Date	Gross Weight in gms.	Soil Moisture Per Cent	Date	Gross Weight in gms.	Soil Moisture Per Cent
1st Period	March 23.....	15,070	27.4	March 27.....	14,733	23.1
2nd Period	April 3......	15,050	27.3	April 6......	14,720	23.0
3rd Period	April 13......	15,140	28.2	April 15......	14,725	23.1

The interesting but not unexpected finding that growth was more rapid during the night than during the day prompted a still more detailed study of this aspect.

The soil was irrigated to maximum field capacity on April 6 and had regained normal growth on the next day. A series of detailed observations was begun on April 8. Due to the cooperation of University students in irrigation courses, it was possible to secure observations at 15-minute intervals for the 26-hour interval beginning at 2:00 p. m. on April 8, and ending at 4:00 p. m. on the following day.

Two optical levers were in use. One on the leaf had the usual 1:20 ratio, while one attached to the last visible dewlap or ligule had a 1:40 ratio. In addition to observations upon growth, the system was weighed upon the even hours as a measure of transpiration losses. Temperature observations were made at 15-minute intervals. A centigrade thermometer was used, readings being made to the nearest tenth of a degree.

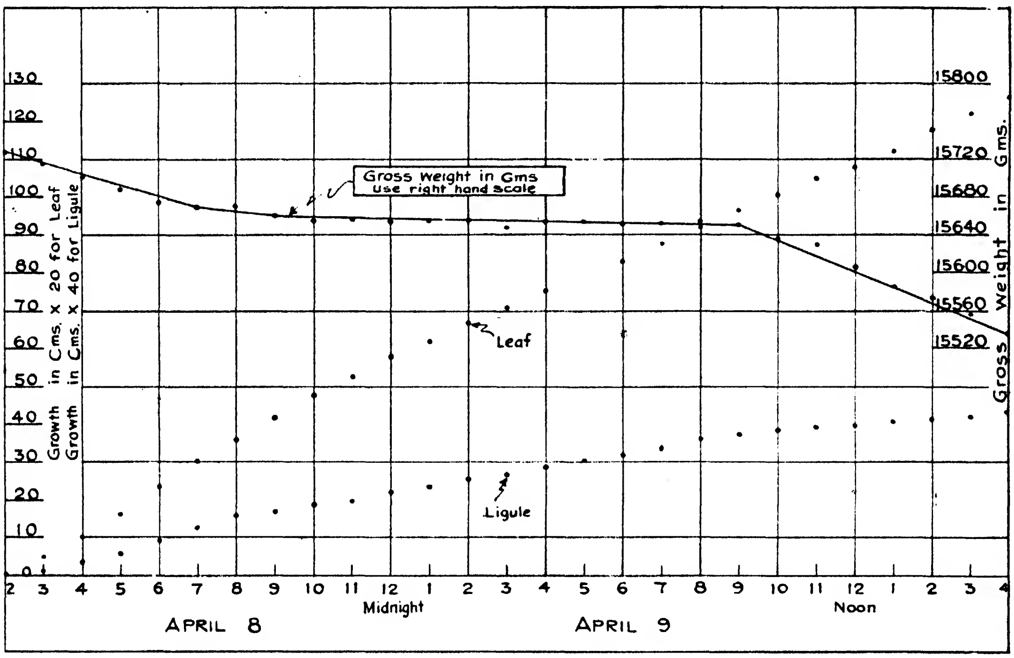


Fig. 4. Growth history of small cane plant for a 26-hour period immediately after an irrigation. Based on observations at 15-minute intervals.

Partial results are presented graphically in Fig. 4. The series of points marked "leaf" gives the growth history of a point on the central spindle. The scale on the left starts from an arbitrary datum. Actual elongation may be secured by dividing the scale increase for any period by 20. Similarly, the lower series of points represents the elongation of the stalk as measured by the last visible ligule. In this case the factor is 40. In each case the detailed observations for the quarter hours are omitted in Fig. 4 for clarity. When plotted they fall close to their interpolated positions.

Little can be judged of relative rates of growth from 4:00 p. m. to 7:00 a. m. and 7:00 a. m. and 4:00 p. m. from Fig. 4 in the case of the leaf bundle. However, statistical interpretation indicates that the elongation is more rapid during the

night than during the day even at the high moisture content present only 48 hours after irrigation. The results are given in Table II.

The difference in rates is more marked in the case of the vertical displacement of the ligule. The average rates for the two periods are given in the following table:

TABLE II

Average Rates of Elongation in Scale Divisions per Quarter Hour for Critical Periods of the Day (See Fig. 4)

	NIGHT			DAY			
	From	To	Elongation*	From	To	Elongation*	Difference
Leaf	4 P.M.	7 A.M.	1.293 ± .028	7 A.M.	4 P.M.	1.092 ± .026	0.201 ± .038
Ligule	4 P.M.	7 A.M.	0.508 ± .020	4 A.M.	7 P.M.	0.244 ± .020	0.261 ± .025

Since a difference is assumed to be statistically significant, if it is five times its probable error, it may be assumed that the growth of both critical points under the conditions of the experiment was more rapid during the night than during the day, the difference being greater in the case of the ligule.

It will be noted, too, from Fig. 4 that losses of moisture by transpiration become almost negligible during the hours of complete darkness. And it is during this period that growth is most rapid. It may be remembered that Curtis (2) once said that transpiration was a necessary evil that evolution would at some time correct.

The thermometer readings mentioned above suggest other interesting relations. As has been noted the growth of both leaf and ligule was more rapid during the night with its low temperatures than during the day. If the period of night be defined as between 4:00 p. m. and 7:00 a. m., a correlation coefficient of +0.671 is secured when the average temperature for a 15-minute interval is compared with growth accomplished during the interval. This coefficient may be interpreted as being significant and the positive sign indicates that higher temperature during the night is associated with more rapid growth. This relation changes at the beginning of the day period, the corresponding correlation coefficient being —0.103. Although such a coefficient is probably not significant, we have some evidence that the relation between temperature and growth noted for the night period is significantly changed. Moreover, the negative sign, if significant, indicates that low temperatures are associated with rapid growth during the day.

Another relation is indicated by a study of the average temperature during the hourly periods elapsing between weighings and the observed losses by transpiration during corresponding periods. The average temperature during the period 4:00 p. m. to 7:00 a. m. was 23.2° C. Between 7:00 a. m. and 4:00 p. m., the average temperature was 26.3° C. During the night period the average transpiration was 6 gms. per hour, while during the day the average transpiration reached a value of 15 gms. per hour. An increase of 150 per cent in transpira-

* Elongation given in scale centimeters per hour. To secure actual growth divide elongation by 20 for leaf and by 40 for ligule.

tion with a temperature increase of 3.1° C. seems out of line with the common understanding of factors influencing evaporation even if the differences in relative humidities during the two periods are considered. A logical conclusion is that sunlight has other influences upon the rate of transpiration than temperature alone. The opening of the stoma during periods of light is well recognized but perhaps not fully understood by plant physiologists (3).

The determination of the permanent wilting percentage of the soil in question by means of the usual procedure with sunflowers gave a value of 23.2 ± 0.2 for this constant.

Discussion

As has been pointed out the arbitrary definition for the permanent wilting percentage is the soil moisture content at the time the leaves of a plant growing upon it first suffer a permanent reduction of their moisture content as a result of deficiency of soil moisture supply. The common criterion as to whether or not the permanent wilting percentage is reached is the exposure of the plant with its flaccid tissue to a saturated atmosphere for twelve hours. Evidently the question of rates is implied, if not expressed. If soil moisture can move into a plant as rapidly as moisture is being lost from its leaf structures by transpiration, no flaccid tissue will result. And if sufficient moisture can move into a plant in the dark in twelve hours to restore complete turgidity, the wilting percentage would not yet be reached by the definition.

Evidently the same conception of rates is involved in the present study of cane growth. It is commonly believed that cell division cannot take place except with perfectly turgid cells, nor can cell enlargement proceed in the case of flaccid tissue. The two factors which might be responsible for the growth responses noted seem dependent upon complete turgor.

Evidently the rate at which moisture may be made available to the plant depends not only upon the rate at which it may be removed from the soil but upon the capacity of the plant structure to convey that moisture to the point of need. Moreover, the transpirational demand seems to vary greatly as indeed one might suppose. A hot, bright day of low humidity might well establish such a demand for water that flaccid tissue might result regardless of the soil-moisture content.

A normal day in the greenhouse seems to approach this condition. Factors making for transpiration are so intense that complete turgidity cannot be maintained, consequently, growth is curtailed. The darkness and coolness of the night seems to re-establish the balance between the rate of income and outgo and complete turgor permits maximum growth. It is very probable that similar observations in a well ventilated greenhouse or in the field, if sufficient precision of measurement might be secured, would fail to disclose the difference between day growth and night growth here reported. If the rate of transpiration is not more than the possible rate of income, normal turgor should prevail and growth should be unaffected.

Another factor is introduced by soil-moisture contents near and below the wilting percentage. Here the residual soil moisture is so firmly held that move-

ment into the root may be at an extremely slow rate. The amounts of water moving into the plant during periods of reduced transpiration become successively smaller as the soil moisture is reduced and the period of most active growth during the day becomes shorter.

It would seem plausible at least to assume that the transitional curve between normal growth and no growth would be less marked with respect to time as well as soil moisture percentages under conditions of constant transpirational demands than under greenhouse conditions. For in the former case no storage of water in the plant would be possible during hours of lessened demand. In the greenhouse, however, or in the field under conditions of hot, dry days and cool nights, one might expect a short period of maximum growth each day at relatively low moisture contents due to the turgid tissue resulting from the reduced transpiration of the night. All observations under greenhouse conditions note a significant retardation curve. At Waipio, under field conditions, the transitional retardation was hardly significant, while at Ewa it was easily noted with field measurements.

This hypothesis seems to find further support in the residual soil-moisture contents at the time of complete growth cessation. As has been noted, growth ceased in all three cases at a moisture content close to 23.0 per cent. From the agreement above, it would follow that a flaccid cane plant in the soil in question was unable to regain sufficient turgor during the hours of the night to resume elongation. If it be assumed that complete turgidity is necessary for growth of this type, the soil-moisture at this point is essentially the permanent wilting percentage. It would follow that the percentage of soil-moisture present when the reduced rate of growth gives place to no growth at all should be numerically equal to the permanent wilting percentage as determined by other plants. The close agreement between 23.2 per cent as the residual soil moisture at permanent wilting of sunflowers and 23.1 per cent at the time of growth cessation seems to support this assumption. The same conclusion has been reached by Shaw and Matsusaka (5) as a result of an exhaustive series of observations upon many soils.

An optical lever for field use is now being constructed.

Summary

(1) An optical device which permits precise measurement of cane elongation at varying soil-moisture percentages is described.

(2) No significant difference is noted between the rate of vertical displacement of a point on the leaf bundle on a cane plant during high soil-moisture percentages and low soil-moisture percentages provided the soil moisture is always at least 3 per cent above the permanent wilting percentage.

(3) A long and significant transition curve between normal growth and no growth is noted under greenhouse conditions.

(4) Growth during the night is at a more rapid rate than growth during the day under greenhouse conditions.

(5) Transpiration losses during the night are small.

(6) It seems reasonable to assume that the period of retarded growth immediately preceding total growth cessation would be reduced in conditions offering less extreme difference in transpirational demands than encountered in the greenhouse. If such be the case, the permanent wilting percentage becomes a close approximation of the soil moisture content at which cane ceases its economic growth.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 17, 1932, TO SEPTEMBER 15, 1932

Date	Per Pound	Per Ton	Remarks
June 17, 1932	2.89¢	$57.80	Philippines, 2.88; Porto Ricos, 2.90.
" 20	2.90	58.00	Cubas, Porto Ricos, Philippines.
" 21	2.835	56.70	Philippines, 2.85; Cubas, 2.82.
" 22	2.80	56.00	Porto Ricos.
" 23	2.90	58.00	Philippines.
" 28	2.8633	57.27	Cubas, 2.88, 2.85; Porto Ricos, 2.86.
" 29	2.80	56.00	Porto Ricos, Philippines.
July 5	2.97	59.40	Philippines.
" 6	2.95	59.00	Porto Ricos, St. Croix.
" 7	2.99	59.80	Porto Ricos, 2.95, 3.00; Cubas, 3.00, 3.02; Philippines, 3.00.
" 8	3.05	61.00	Cubas, Porto Ricos, Philippines.
" 14	3.1167	62.33	Cubas, 3.10, 3.12; Porto Ricos, 3.10, 3.13.
" 18	3.10	62.00	Philippines.
" 27	3.07	61.40	Cubas.
Aug. 2	3.08	61.60	Porto Ricos.
" 3	3.085	61.70	Philippines; Cubas, 3.09, 3.08.
" 4	3.08	61.60	Philippines.
" 8	3.10	62.00	Cubas, Philippines, Porto Ricos.
" 9	3.1233	62.47	Porto Ricos, 3.10, 3.15; Cubas, 3.12, 3.15.
" 10	3.15	63.00	Cubas, Porto Ricos, Philippines.
" 11	3.14	62.80	St. Croix.
" 12	3.15	63.00	Cubas.
" 16	3.18	63.60	Cubas, Philippines.
" 19	3.17	63.40	Cubas.
" 26	3.18	63.60	Cubas, Porto Ricos.
Sept. 7	3.16	63.20	Cubas.
" 8	3.15	63.00	Cubas, Philippines.
" 12	3.10	62.00	Cubas.
" 15	3.08	61.60	Cubas.

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